No. 195. Vol. XXXIII. MARCH, 1887.

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THE

AMERICAN

JOURNAL OF SCIENCE.

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THIRD SERIES.

VOL. XXXIII.—[WHOLE NUMBER, CXXXIII.]

No. 195—MARCH, 1887.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1887.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & Co., New York.—**Manual of Geology,** by J. D DANA. **Third Edition,** 1880. 912 pp. 8vo. $5.00.—**Text-book of Geology** by the same. **4th ed.** 1883. 412 pp. 12mo. $2.00.—**The Geological Story Briefly Told,** by the same. 264 pp. 12mo. 1875.

J. WILEY & SONS, New York.—**Treatise on Mineralogy,** by J. D. DANA. 5th edit. xlviii and 828 pp. 8vo., 1868. $10.00. The 5th "subedition" was issued by Wiley & Son in April, 1874. (Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication). Also, Appendix I. by G. J. Brush. 1872. Appendix II, by E. S. Dana, 1875.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 3d edition. 474 pp. 12mo., 1878.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.—**Manual of Determinative Mineralogy,** with an Introduction on Blow-pipe Analysis, by GEORGE J. BRUSH. 8vo., 2d ed. 1877. Third Appendix to Dana's Mineralogy, by E. S. DANA. 136 pp. 8vo. 1882.

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XX.—*On the Absolute Wave-length of Light;* By LOUIS BELL, Fellow in Physics in Johns Hopkins University.

UP to the present time, Ångström's map of the solar spectrum and with it his determination of absolute wave length, has remained the final standard of reference in all spectroscopic matters. But since Ångström's work was published, optical science, particularly that part of it which deals with the manufacture and use of diffraction gratings, has made enormous progress. It is now possible with the concave grating to measure relative wave-lengths with an accuracy far greater than can be claimed for any one of the absolute determinations. The numbers given by Ångström are now known to be too small by as much as one part in seven or eight thousand, as has been shown by Thalén in his monograph "Sur le spectre du Fer," and since Ångström's work but one careful determination has been made. This is by Mr. C. S. Peirce and was undertaken some eight years since for the U. S. Coast and Geodetic Survey. No full report of this work has as yet been published, though it is evidently very careful and has already consumed several years. Certain results were communicated to Prof. Rowland of this University to serve as a standard of reference for his great map of the solar spectrum now nearly completed, and it was to serve as a check on these results and to furnish a value of the absolute wave length as nearly as possible commensurate in accuracy with the micrometrical observations, that the experiments detailed in the present paper were undertaken. Only the work

with glass gratings has been as yet completed, but since the relative wave lengths, which are intrinsically of far greater importance, are now ready for publication and have been reduced by the value herein given, the result is published, leaving for further work with speculum metal gratings, its final confirmation or correction.

This portion of the determination is delayed awaiting better facilities for carrying it out, but the writer intends undertaking it at the earliest possible moment and hence leaves for a future paper the complete discussion of the problem.

The writer desires here to express his deep obligations to Prof. Rowland, under whose guidance the work has been carried on and to whom a very important correction is due, and to Profs. W. A. Rogers and C. S. Peirce for information given and courtesies extended.

Experimental.

The determination of absolute wave-length involves two quite distinct problems—first, the exact measurement of the angle of deviation of the ray investigated, and second, the measurement of the absolute length of the gratings used. Each portion of the work involves its own set of corrections, frequently quite complicated and difficult, but it is the latter part that is peculiarly liable to errors, which will be treated in detail further on. As to the former part, several important questions arise at the very outset. First is the choice between transmission and reflection gratings. The principal work heretofore has been done with the former, but metallic gratings possess certain advantages, notably from the ease with which their temperature can be accurately measured, and the fact that they can easily be made of a size much larger than glass gratings, and consequently a small inaccuracy in measuring them involves much less error in the result.

On the other hand the coefficient of expansion of speculum metal is more than twice as great as that of glass, and being a good conductor it is far more sensitive to small changes of temperature. And this property increases the liability to irregularities in the ruling, particularly in large gratings which require several days for completion. In ruling on glass change of temperature is less serious but this advantage is more than offset by the faults caused by the wearing away of the diamond point, which breaks down so rapidly that it is enormously difficult to produce a glass grating free from flaws and at all comparable in optical excellence with those upon speculum metal. The determination of absolute wave-length should rest on measurements made with both classes, and with sufficiently exact instruments and very careful experimentation, the better results

can probably be obtained from the metallic gratings. For the reasons previously stated, this paper is confined to the results from glass ones.

Now there are two quite distinct ways of using transmission gratings—first, perpendicular, or nearly so, to collimating or observing telescope; and second, in the position of minimum deviation. The method in the first case is familiar—the properties of the second are as follows:

The general relation between the incident and the diffracted ray is:

$$\sin i + \sin (\delta - i) = \frac{m\lambda}{a}.$$

When $i=o°$, this gives the ordinary formula for normal incidence. Putting it in the form—

$$\lambda = \frac{2(a)}{m} \sin \frac{\delta}{2} \cos (i - \frac{\delta}{2}),$$

the deviation represented by the angular term will evidently be a minimum when $i=\frac{\delta}{2}$ and the wave-length will then be given by the formula

$$\lambda = \frac{2(a)}{m} \sin \frac{\delta}{2}.$$

It is not easy to say which method of procedure is preferable, but on the whole the ordinary plan of normal incidence offers fewer experimental difficulties and therefore was adopted, particularly as the spectrometer used was specially well suited to that method. It is quite certain that either method will with proper care give the angular deviation with a degree of exactness far surpassing that attainable in the measurement of the gratings.

The Spectrometer.

This was a large and solid instrument by Meyerstein with a circle on silver 32^{cm} in diameter divided to tenths of a degree. This is read by two micrometer microscopes 180° apart. The pitch of the micrometer screws is such that one turn equals about 2′, and as the head is divided into sixty parts each of these represents 2″. The micrometer can, however, be set with certainty to less than half this amount. The collimating and observing telescopes are of 4^{cm} clear aperture and 35^{cm} focal length and the lenses are well corrected. The collimator is fixed to the massive arms which carry the reading microscopes while the observing telescope is attached to a collar on the axis of the main circle and moves freely upon it or can be firmly clamped so as to move with the circle. The grating is carried

on an adjustable platform with a circle 12·5^{cm} in diameter, divided to 30′ by verniers to 1′ and moving either upon or with the large circle.

This arrangement of parts does not admit of fixing the grating rigidly normal to the collimator, so in all the experiments it was placed normal to the observing telescope, a position which was particularly advantageous in the matter of adjustment. The instrument was set up in a southern room in the physcial laboratory and throughout the experiments the collimator pointed about south-southeast. With the eyepiece used the observing telescope had a power of very nearly sixteen diameters.

Gratings.

Very few glass gratings have ever been ruled on Prof. Rowland's engine, since for most purposes they are much inferior to the metallic ones, and are very much more difficult to rule, as they run great risk of being spoiled by the breaking down of the diamond point. A very few, however, were ruled in 1884 with special reference to wave-length determination, and of these the two best were available for these experiments. They are both ruled upon plane sextant mirrors, and are of very nearly the same size—thirty millimeters long, with lines of about nineteen millimeters. Each hundredth line is longer, and each fiftieth line shorter than the rest, so that the gratings are very easy to examine in detail. The ruling of both is smooth and firm, without breaks or accidental irregularities and almost without flaws. They were ruled at different temperatures and on different parts of the screw, and while one was ruled with the ordinary arrangement of the engine, the other was ruled to a very different space by means of a tangent screw. This great diversity of conditions in the two gratings is far from favoring a close agreement in the results, but tends to eliminate constant errors due to the dividing engine, and hence to increase the value of the average result. It must be remembered that two gratings ruled on the same part of the screw are in most respects little better than one. The grating designated I in this paper contains 12,100 spaces, at the rate of very nearly 400 to the millimeter, and was ruled (by tangent screw) at a temperature of 6°·7 C. in January, 1884. It gives excellent definition with almost exactly the same focus for the spectra on either side, and is quite free from ghosts or other similar defects.

The grating designated II has 8,600 spaces, at the rate of about 7,200 to the inch, and was ruled in November, 1884, at 11°·6 C. Its definition and focussing are very nearly as good as in I and like it, it shows no trace of ghosts or false lines; they

are both exquisite specimens of the work which Prof. Rowland's engine is capable of doing, though as the event showed, I is decidedly the better grating, in the matter of regularity of ruling.

Angular Measurements.

At the beginning of the work a serious question of adjustment arose. There are two ways of using a grating perpendicular to one of the telescopes. In the first place it may be placed and kept accurately in that position, and secondly it may be placed nearly in the position for normal incidence, and the error measured and corrected for. Ångström used the latter method, which involved a measurement on the direct image of the slit as well as on the lines observed. Using Ångström's notation—let α and α' be the readings on the spectra, and M that on the slit. Let, also,

$$\frac{\alpha+\alpha'}{2} - \mathrm{M} = \Delta \quad \text{and} \quad \frac{\alpha-\alpha'}{2} = \varphi.$$

Then if γ is the angle made by the incident ray with the normal to the grating, and N the order of spectrum,

$$\frac{\mathrm{N}\lambda}{\varepsilon} = \cos(\gamma+\Delta)\sin\varphi;$$

also $$\sin\gamma = \sin(\gamma+\Delta)\cos\varphi,$$

and $$\tan\gamma = \frac{\cos\varphi}{1-\cos\varphi}\Delta.$$ But from the second of the above equations,

$$\sin(\gamma+\Delta) = \frac{\sin\gamma}{\cos\varphi}.$$

Now it was found that with the collimating eyepiece belonging to the spectrometer, γ would never exceed and seldom reach 10″, while the angles of deviation observed were about 45°. Substituting these values in the last equation, it at once appeared that the cosine of $(\gamma+\Delta)$ was a quantity differing from unity by considerably less than one part in a million, and hence entirely negligible. Further, it was found that the grating once set could be trusted to remain perpendicular through a series of measurements, and though at the end of each series the grating was adjusted to a new part of the circle, and a close watch was kept for its slipping out of adjustment, it was never found necessary to reject a series from that cause.

The grating was centered and adjusted with reference to the circles and their axes by the ordinary methods. Throughout the experiments the light was concentrated on the slit by an achromatic lens of about half a meter focus, which was placed behind a sheet of deep yellow glass, which served to cut off the

overlapping blue rays which might otherwise have proved troublesome. A heliostat enabled the sun's image to be kept centrally upon the slit.

The method of observation was as follows: When instrument and grating were in exact adjustment, readings were taken on D_1 in the spectra on either side of the slit, and the angle measured from three to six times in rapid succession, the last reading being of course on the same side as the first.

Then the grating was rotated about ten degrees, readjusted, and the process repeated.

The angles observed in one series were combined to eliminate errors of setting, while the use of all portions of the circle served to correct errors of subdivision, since the number of independent series of observations was quite large.

To eliminate any errors which might be due to imperfections of figure in the gratings they were used in all the four possible positions. No such error, however, became apparent either from critical examination of the gratings themselves, or from the results obtained in the different positions.

Observations with grating I were begun late in October, 1885, and occupied the clear days for a month. Forty-eight series of measurements were made, and the agreement between them was very satisfactory. After correcting for temperature, thirty-six of the number fell within a range of three seconds and the rest were clustered closely about them. Observations on the various days were as follows:

Date.	Number of Series.	Angle.
Oct. 19	1	45° 1′ 47″·2
20	1	45° 1′ 48″·4
22	2	45° 1′ 48″·2
23	1	45° 1′ 49″·8
26	4	45° 1′ 49″·3
27	3	45° 1′ 48″·2
31	1	45° 1′ 50″·1
Nov. 3	1	45° 1′ 48″.6
4	3	45° 1′ 47″·4
5	2	45° 1′ 47″·9
10	4	45° 1′ 47″·8
11	6	45° 1′ 49″·7
16	8	45° 1′ 48″·2
17	5	45° 1′ 47″·5
20	6	45° 1′ 47″·5

All the above were in the third spectrum to which measurements were in the main confined as in it the definition was particularly good, and it being the highest order which could be conveniently observed, an error in the angle would produce the

minimum effect. The spectra on both sides of the slit were about equal in brilliancy and definition.

The observations were weighted as nearly as possible according to the favorable or unfavorable conditions under which they were made, and when finally combined gave as the value of the angle of deviation for grating I,

$$\varphi = 45^\circ\ 1'\ 48''{\cdot}24 \pm 0''{\cdot}11.$$

The above probable error is equivalent to a little less than one part in a million and can introduce no sensible error into the resulting wave length.

Other work intervened and the measurements with grating II were not taken up until early in the succeeding March. Precisely the same method of observation was employed and the results were nearly as consistent and satisfactory.

The observations by days were as follows:

Date, 1886.	Number of Series.	Angle.
March 6	2	42° 5′ 1″·2
10	1	42° 4′ 58″·6
11	7	42° 5′ 1″·4
15	1	42° 5′ 4″·0
16	6	42° 4′ 57″·8
17	6	42° 4′ 58″·5
18	7	42° 4′ 59″·1
23	6	42° 4′ 58″·3

When collected thus by days the observations do not appear to agree nearly as well as those made with grating I, particularly since a solitary wild reading, that of March 15, is retained. The distribution of the various readings, however, is such that after weighing and combining the final result is by no means deficient in accuracy. It is,

$$\varphi = 42^\circ\ 4'\ 59''{\cdot}28 \pm 0''{\cdot}2$$

The above probable error amounts to about one part in six hundred thousand. The observations with grating II were uniformly in the fourth order of spectrum.

Throughout the measurements with both gratings the temperature was kept within a few degrees. 20° C. had been selected as the standard temperature and the variation was rarely more than two or three degrees on either side of that figure. The question of temperature determination is a serious one in case of glass gratings, for it is very hard to tell what heating effect the incident beam has on the grating, and equally hard to measure that effect. It is hardly safe without extraordinary precautions to assume that the grating has the same temperature as the air near, and it is such a bad conductor that it would not easily assume the temperature of the apparatus. In

these experiments a sort of compromise was effected. A small thermometer was attached to the thin metallic slip that held the edge of the grating, and shielded by cotton from air currents which of course would affect it much more than they would the grating. The thermometer was a small Fahrenheit graduated to quarter degrees and quite sensitive. It was carefully compared, throughout the range of temperatures employed, with thermometer Baudin 7312, which served as a standard in all the measurements regular and linear, and during part of the time was placed directly over the grating to give a check on the attached thermometer. This expedient was finally abandoned as unlikely to help the matter much.

The corrections for temperature were deduced from the assumed coefficient of expansion of glass, which was taken as 0·0000085. This was reduced to angular correction for the approximate value of φ and applied directly to the observed angles. Since the temperatures at which observations were made varied little from 20° C. and were quite equally distributed on both sides of that figure any error in the assumed coefficient would hardly affect the average result, but would appear, if at all, as a slight increase in the probable error.

760^{mm} (reduced) was taken as standard pressure and the values for the days of observation were taken from the U. S. Signal Service observations for the hours of 11 A. M. and 3 P. M. on those days. The average for the measurements made with grating I was 761^{mm}, and for those with grating II 760^{mm}, so that corrections for pressure were uncalled for.

The effect of the velocity of the apparatus through space is a subject concerning which there has been much discussion. Ångström deduced a correction, but van der Willigen in quite a lengthy discussion of the whole matter came to the conclusion that there was no error due to the above cause. Since that period the question has been raised from time to time, but no decisive investigations on the subject have yet been published. At present however it seems to be tolerably well settled that no correction is needed, as the error, if there be any, is of an order of magnitude entirely negligible, and in the present paper none has been applied.

The angular measurements, after all corrections were applied, may thus be regarded as determined with a high degree of accuracy—most probably to less than one part in half a million.

Measurement of the Gratings.

The exact determination of the grating space is by far the most difficult portion of a research on absolute wave length, and has been uniformly the most fruitful source of errors.

Besides the experimental difficulties of the task, it is far from an easy matter to secure proper standards of length. The standards used in various former investigations have proved to be in error, sometimes by a very considerable amount, and indeed very few of the older standards are above suspicion. As Peirce has very justly remarked in connection with this subject, "All exact measures of length made now must wait for their final correction until the establishment of the new metric prototype." Short standards of length are in some respects peculiarly liable to error, since they must be compared with the subdivisions (often not sufficiently well determined) of secondary standards, and small sources of uncertainty such as poor defining lines, slight changes in the apparatus and the like, of course are much more serious as the length is less.

Fortunately there were available for the measurement of the gratings two standard double decimeters which have been determined with almost unprecedented care by Professor W. A. Rogers. They are upon speculum metal; were graduated and determined by Professor Rogers early in 1885 and were purchased by the university late in the same year. They are designated respectively S_1^a and S_2^a and are discussed at length in the Proceedings of the American Society of Microscopists for 1885.

The bar S_1 is 23^{cm} in length. Near one edge is the double decimeter S_1^a divided to centimeters, the 5^{cm} lines being triple. S_2 is 27^{cm} in length and graduated in the same way. The defining lines in both are fine and sharp and the surfaces are accurately plane. They are standard at $16°{\cdot}67$ C. and from an elaborate series of comparisons with four different standards the coefficient of expansion was found to be,

$$17{\cdot}946\ \mu \text{ per meter per degree C.}$$

S_1^a and S_2^a depend for their accuracy on a long series of independent comparisons with Professor Rogers' bronze yard and meter R_2 and steel standards whose relation to R_2 was very exactly known. R_2 has been determined by elaborate comparisons with various standard meters and yards, and is described and discussed at length in the Proceedings of the American Academy, vol. xviii. The length of the meter was determined both directly and through the yard, by comparison with the following standards:

I. The meter designated T, copper with platinum plugs, traced and standardized by Tresca in 1880 from the Conservatoire line metre No. 19, which bears a very exactly known relation to the Metre des Archives.

II. The yard and meter designated C. S., brass with silver plugs, belonging to the Stevens Institute. The yard was compared with the Imperial Yard in 1880 so that it is directly and

exactly known. It was afterwards sent to Breteuil and the meter was determined with great exactness by elaborate comparisons with type I of the International Bureau of Weights and Measures.

III. "Bronze 11" a primary copy of the Imperial Yard presented to the United States in 1856. It was taken to England in 1878 and finally determined by direct comparison with the Imperial Yard, Bronze Yard No. 6, and Cast Iron Yards B No. 62 and C No. 63.

The subdivisions of R_2 have been determined with very great care, and thus S_1^a and S_2^a, whose lengths relative to R_2 are accurately known, may finally be referred to the ultimate standard Type I of the International Bureau.

Only the 5^{cm} spaces of S_1^a and S_2^a were investigated by Prof. Rogers, but these were determined by various methods under widely different conditions, and their relations to the standards with which they were compared may be regarded as definitely known. From a combination of all results the subdivisions of S_1^a have the following lengths at the standard temperature.

$$\begin{aligned}
\text{Standard } S_1^a &= 199{\cdot}99918^{mm} \\
{}^{dm}_{1}\,S_1^a &= 99{\cdot}99995 \\
{}^{dm}_{2}\,S_1^a &= 99{\cdot}99923 \\
{}^{5^{cm}}_{1}\,S_1^a &= 50{\cdot}00010 \\
{}^{5^{cm}}_{2}\,S_1^a &= 49{\cdot}99985 \\
{}^{5^{cm}}_{3}\,S_1^a &= 49{\cdot}99901 \\
{}^{5^{cm}}_{4}\,S_1^a &= 50{\cdot}00022
\end{aligned}$$

Similarly the following values were derived for S_2^a.

$$\begin{aligned}
\text{Standard } S_2^a &= 199{\cdot}99968^{mm} \\
{}^{dm}_{1}\,S_2^a &= 100{\cdot}00001 \\
{}^{dm}_{2}\,S_2^a &= 99{\cdot}99967 \\
{}^{5^{cm}}_{1}\,S_2^a &= 50{\cdot}00020 \\
{}^{5^{cm}}_{2}\,S_2^a &= 49{\cdot}99981 \\
{}^{5^{cm}}_{3}\,S_2^a &= 49{\cdot}99931 \\
{}^{5^{cm}}_{4}\,S_2^a &= 50{\cdot}00042
\end{aligned}$$

As to the degree of accuracy attained in determining S_1^a and, S_2^a, Prof. Rogers says that including all sources of uncertainty either standard may have an error of $\pm 0{\cdot}3\mu$, but the mean of the two, since the determinations were independent ought to be even more reliable. Taking all things into consideration it seems very improbable that the mean value of S_1^a and S_2^a can be in error by as much as one part in half a million.

So much for the standards of length. The comparator used in the measurements was a very efficient instrument, particularly suited for the purpose. It consisted essentially of a long carriage ($\frac{1}{2}$ meter) running on V-shaped ways and carrying the microscope. This carriage slides against adjustable stops, and

is pressed against them with perfect uniformity by means of weights. An adjustable platform below carries the standards and objects to be measured. The ways of both carriage and platform had been ground till they were perfectly uniform and true and the working of the instrument left little to be desired in the way of accuracy. Throughout a long series of measurements the stops would not be displaced by so much as $0{\cdot}1\mu$ if proper care were used in moving the carriage. The microscope was attached so firmly as to avoid all shaking, and was armed with a half-inch objective and an excellent eyepiece micrometer. The objective was made specially for micrometric work and was fitted with a Tolles' opaque illuminator. Measurements were made as follows: The standard bar, and the grating mounted on a polished block of speculum metal, were placed side by side,—or sometimes end to end,—on the platform and very accurately leveled. The stops were set very nearly three centimeters apart, one end of the grating brought under the microscope resting against one of the stops, and the micrometer set on the terminal line. Then the carriage was brought against the other stop and the micrometer again set. The same process was then gone through with on three centimeters of the standard, and then going back to the grating it was compared in the same manner with succeeding triple centimeters till the fifteen centimeter line was reached, thus eliminating the errors of the single centimeters and making the determination rest only on the fifteen centimeter line. The temperature was given by a thermometer placed against the standard bar or the block that carried the grating. In this manner each grating was repeatedly compared with the first 15 centimeters of each bar, at or near 20°, the temperature at which the gratings had been used. The micrometer constant was determined by measuring tenths of millimeters ruled on Prof. Rowland's engine, but in practice the stops were so adjusted that it was almost eliminated. Each division of the micrometer head equalled $0{\cdot}28\mu$ and the probable error of setting was less than half that amount.

All measurements were reduced to 20° C. as in case of the angular determinations. The line along which the linear measures were made was that formed by the terminations of the rulings. It therefore was necessary to know very exactly the angle between this line and the direction of the individual rulings, in other words the angle between the line of motion of the grating and the direction of the diamond stroke in the dividing engine. This was ascertained by means of two test plates each some twelve cm. long ruled in cms. and then superimposed line for line. By measuring the minute distances between each end of a pair of superimposed lines, the length of the lines and the amount by which their ends overlapped at each end of the test

plate, the required angle could be deduced with great exactness. It differed so little from 90° however, that the correction produced, barely one part in a million, was entirely negligible.

After all reductions and corrections, the following series of values were obtained for the grating spaces of gratings I and II.

Series.	Grating I.	Standard.
1	0·00250023^{mm}	S^a_2
2	0·00250016	"
3	0·00250013	"
4	0·00250015	"
5	0·00250018	"
6	0·00250021	S^a_1
7	0·00250023	"
8	0·00250023	"
9	0·00250023	"

Mean value adopted after weighting and combining the above observations was:

$$0{\cdot}002500194^{mm} \pm 10$$

The probable error thus appears to be not far from one part in two hundred and fifty thousand. The difference in the results obtained from the two standards seems to be purely accidental as appears from the measurements on grating II.

Series.	Grating II.	Standard.
1	0·00351888^{mm}	S^a_1
2	0·00351883	"
3	0·00351885	"
4	0·00351886	"
5	0·00351883	"
6	0·00351893	S^a_2
7	0·00351888	"
8	0·00351888	"
9	0·00351888	"

Mean adopted, $0{\cdot}003518870 \pm 10$

The probable error appears to be rather less than in the measurements of grating I. As however the angular determinations made with I are the better, so far as probable errors of observation are concerned the result from the two gratings are about equal in value.

Computing now the wave-length corresponding to the given values of φ and δ for each grating, we have finally for the wave-length of D_1 at 20° C. and 760^{mm} pressure:

From Grating I uncorrected, 5896·11 tenth meters.
From Grating II " 5895·95 "

The difference in the above results is by no means large compared with the results obtained from different gratings by other investigators, but it certainly is enormously great compared with the experimental errors alone.

As nearly as can be judged these ought not in either grating to exceed one part in two hundred thousand, while the above discrepancy is about one part in thirty-five thousand.

Its cause must be sought in the individual peculiarities of the gratings, rather than in the method of using them.

All gratings are subject to irregularities of ruling, and the effects of these is various, according to the nature and magnitude of the defects. Linear or periodic errors in ruling, unless very small, will make themselves apparent by changing the focus of the spectra or producing ghosts, respectively; and if such errors are large, render the grating totally unfit for exact measurement. Accidental errors, such as a flaw or break in the ruling, are also serious, but are easily detected and may be approximately corrected, as was done by Ångström in the case of one of his gratings. Any marked and extensive irregularities of spacing will produce bad definition or false lines, and in most cases both. If, then, a grating on microscopical examinations is free from flaws and on the spectrometer gives sharply defined spectra, alike in focus and free from ghosts, it is safe to conclude that it is tolerably free from the errors above mentioned, but unfortunately there is one fault that does not at once become visible, while it introduces a very serious error in the measurements. This is a rather sudden change in the grating space through a portion of the grating, usually at one end. Such an error is usually due to abnormal running of the screw when the dividing engine is first started, and may in this case be avoided by letting the engine run for some time before beginning to rule. Thus Grating I, ruled with this precaution, is nearly free from this error. Sometimes, however, it is the terminal or an intermediate portion of the grating that is thus affected in which case the error may be due to a change of temperature or to a fault in the screw. If an error of this kind is extensive, it will produce the effect of two contiguous gratings of different grating space, injuring the definition and widening or reduplicatiug the lines. When, however, the abnormal spacing is confined to a few hundred lines it produces no visible effect when the whole grating is used, but simply diffuses a small portion of the light and increases or decreases the average grating space. For it is evident that such a portion of the grating must possess little brilliancy and less resolving power, and the more its spacing differs from that of the rest of the grating, the less chance of visible effect and the greater error introduced. Such a fault is compatible with the sharpest

definition, but can be detected by cutting down the aperture of the grating till the spectrum from the abnormal portion is relatively bright and distinct enough to be seen. The effective grating space, producing the spectra on which measurements are made is, of course, that of the normal portion only. Both the gratings used in these experiments were affected by the above error, No. I, very slightly, No. II, somewhat more seriously. Not only the discrepancies between different gratings, but those between different orders of spectra in the same grating are due to this cause. For while in one order, where the effect due to the abnormal portion is imperceptible, the spectrum as measured is produced by the effective grating space alone, in another order there may be produced a slight shading off of the lines so that their apparent centers may correspond approximately to the average grating space. In any case, it is quite clear that a combination of the results from different orders of spectra will not eliminate the error.

The remedy lies either in stopping out the imperfect portion of the grating, or measuring it and introducing a correction. As the work of angular measurements was nearly finished before the study of the gratings was begun owing to a delay in getting apparatus, the latter course was adopted in these experiments. Each grating was examined in detail, and the relation of the grating spaces in the various portions of it carefully determined. From these data a simple graphical method gave the correction to be applied to the wave length. In each grating the fault was confined to a small portion, and as the order of spectrum employed in each was selected on account of its good definition and freedom from anything like haziness or shading of the lines, it seems safe to assume that the abnormal portion produced no visible effect and that consequently the correction above mentioned counteracts the error quite effectually. In grating I the correction was one part in 300,000, and in grating II one part in 60,000. Applying these to the wave lengths we have for grating I,

Wave length	5896·11
Correction	−·02
Corrected w. l.	5896·09

And for grating II,

Wave length	5895·95
Correction	+·10
Corrected w. l.	5896·05

Combining these and giving to Grating I the greater weight

on account of its very small error of ruling, we have finally for the wave length of D_1 at 20° C. and 760^{mm} pressure,

5896·08 or *in vacuo*, 5897·71

It is no easy matter to give any well founded estimate of the probable error of the above result. So far as experimental errors are concerned the result with either grating should be correct to one part in two hundred and fifty thousand, but the error in the gratings introduces a complication by no means easy to estimate. As nearly as the writer can judge, however, it seems probable that the error of the final result does not exceed one part in two hundred thousand. For comparison, the values deduced from the work of Peirce and of Ångström are subjoined.

Micrometer measure by Rowland, from Peirce's preliminary result ..... 5896·22
Thalen's correction of Ångström ..... 5895·89
both being in air at ordinary temperature and 760^{mm}.

As neither result was corrected for errors in the gratings the cause of the discrepancy is obvious.

Two determinations of absolute wave length have been published since this work was undertaken by the writer. One is a very elaborate one by Müller and Kempf, who employed four gratings by Wanschaff and used the method of minimum deviation. Their results were as follows:

Grating	(2151)	(5001)	(8001)	(80014)
Wave length...	5896·46	5896·14	5895·97	5896·33

By a correction founded on the unwarrantable assumption that the mean value was correct the above results are brought into apparent agreement. Nothing, however, short of a study in detail of each grating can furnish data for obtaining anything like an accurate result from the above figures. It would seem that (5001), which had the smallest probable error, should show but a trifling error of ruling, while one would expect to find a portion or portions of (2151), in which the grating space is abnormally large. Corresponding errors of ruling should appear in (8001) and (80014). A similar study of the gratings used by Ångström would be of no little interest.

The other determination alluded to is one by M. de Lépinay, using a quartz plate and Talbot's bands. Without discussing the method it is sufficient to say that the result obtained depends on the relation of the liter to the decimeter, a ratio not at present exactly determined.

The results detailed in this paper are in a certain sense preliminary. The writer hopes that in the near future, experiments with metallic gratings will enable him to lessen the

probable error very materially and therefore defers, for the present, further discussion of the problem.

Through the courtesy of Mr. Peirce the writer has been enabled to test the legitimacy of the above correction and at the same time check his own results. Mr. Peirce kindly forwarded his gratings and standard of length for examination and comparison, and the results were decidedly instructive.

Grating "H," with which a large part of the work was done, showed, as was suspected, a local error, equivalent to a correction of one part in 55000 in the resulting wave length. Tested in the spectrometer, the portion including the error showed a grating space distinctly greater than that of the grating taken as a whole, showing thus both the necessity and the algebraic sign of the correction. The other gratings showed similar errors varying in amount, but the same in sign, the correction requiring in every case a reduction in the wave length. The abnormal portion was invariably at one end or the other of the grating concerned, never in the middle.

The standard of length used by Mr. Peirce—"No. 3" a glass decimeter—was compared with S_1^a and S_2^a and the preliminary results show that the length assigned to it was too great by very nearly 2μ, 1 part in 50000. Now the wave length of D_1 as deduced from grating H was,

	5896·26
Less error of ruling..	—·10
Less error of "No. 3"	—·12
Corrected value.....	5896·04 in air at 30 in. pressure and 70° F;

which shows a tolerably close correspondence with the results obtained by the writer. A more complete discussion of Peirce's results is reserved until the relation between "No. 3" and S_1^a and S_2^a shall be more exactly known. The latter standards would appear to be the more trustworthy, since they are based on various independent determinations, while "No. 3" is based on an indirect comparison with meter "No. 49," a standard concerning the exact length of which there seems to be some little doubt.

ART. XXI.—*On the Relative Wave-length of the Lines of the Solar Spectrum;* by HENRY A. ROWLAND.

FOR several years past I have been engaged in making a photographic map of the solar spectrum to replace the ordinary engraved maps and I have now finished the map from the extreme ultra violet, wave length 3200, down to wave length 5790. In order to place the scale correctly on this map, I have

found it necessary to measure the relative wave lengths of the spectrum and to reduce it to absolute wave lengths by some more modern determination. I have not yet entirely finished the work, but as my map of the spectrum is now being published and as all observers so far seem to accept the measures of Ångström, I have decided that a table of my results would be of value. For as they stand now they have at least ten times the accuracy of any other determination. This great accuracy arises from the use of the concave grating which reduces the problem of relative wave lengths to the measure of the coincidences of the lines in the different spectra by a micrometer.

The instrument which I have employed has concave gratings 5 or 6 in. diameter, having either 7200 or 14,400 lines to the inch and a radius of 21 ft. 6 in. By my method of mounting, the spectrum is normal where measured, and thus it is possible to use a micrometer with a range of 5 inches. The spectrum keeps in focus everywhere and the constant of the micrometer remains unchanged except for slight variations due to imperfections in the workmanship. The micrometer has no errors of run or period exceeding the $\frac{1}{100000}$ inch. The probable error of a single setting on a good clear line is about $\frac{1}{200000}$ of the wave length. 1″ of arc is about ·0012 inch. The D line in the second spectrum is ·17 inch or 4·4^{mm} wide. Determinations of relative wave length of good lines seldom differ 1 in 500,000 from each other and never exceed 1 in 100,000, even with different gratings. This is, of course, for the principal standard lines, and the chance of error is greater at the extremities of the spectrum. The interpolation of lines was made by running the micrometer over the whole spectrum, 5 inches at a time, and adding the readings together so as to include any distance, even the whole spectrum. The wave length is calculated for a fixed micrometer constant and then corrected so as to coincide everywhere very nearly with the standards. I suppose the probable error of the relative determinations with the weight 1 in my table to be not far from 1 in 500,000. Ångström thinks his standard lines have an accuracy of about 1 in 50,000 and ordinary lines much less.

As to the absolute measure, it is now well determined that Ångström's figures are too small by about 1 part in 6000. This rests: 1st, on the determination of Peirce made for the U. S. Coast Survey with Rutherfurd's gratings and not yet completely published; 2nd, on an error made by Tresca in the length of the standard meter used by Ångström* which increases his value by about 1 in 7700; 3d, on a result obtained

* Thalen, Sur Spectre du Fer Société Royale des Sciences d'Upsal, September, 1884, p. 25.

in my laboratory with two of my gratings by Mr. Bell, which is published with this paper. Mr. C. S. Peirce has kindly placed his grating at our disposal and we have detected an error of ruling which affects his result and makes it nearly coincide with our own. The wave length of the mean of the two E lines is

Ångström (atlas)	5269·12 ± ·05
" (Corrected by Thalen)	5269·80*
Peirce	5270·16
" (Corrected by Rowland and Bell)	5270·00†
Bell	5270·04

These results are for air at ordinary pressures and temperatures. The last is reduced to 20° C. and 760^{mm} pressure. To reduce to a vacuum, multiply by the following:

Fraunhofer line	A	C	E	G	H
Correct'n factor	1·000291	1·000292	1·000294	1·000297	1·000298

The relation between my wave lengths and those of Ångström are given by the following, Ångström's value being from p. 31 of his memoir.

	A (edge)	B (edge)		C	
Ångström	7597.5	6867·10	6717·16	6562·10	6264·31
Rowland	7593·97	6867·38	6717·83	6562·96	6265·27
Difference	− 3·5	·28	·67	·86	·96
	D_2	D_1		Peirce's line	
Ångström	5895·13	5889·12	5708·45	5623·36	5454·84
Rowland	5896·08	5890·12	5709·56	5624·70	5455·68
Difference	·95	1·00	1·11	1·34	·84
	E	E	b_1		F
Ångström	5269·59	5268·67	5183·10	5138·78	4860·74
Rowland	5270·43	5269·65	5183·73	5139·47	4861·43
Difference	·84	·98	·63	·69	·69
		G			
Ångström	4702·44	4307·25			
Rowland	4703·11	4307·96			
Difference	·67	·71			

The greatest variation in these differences is evidently due to the poor definition of Ångström's grating by which the numbers refer to groups of lines rather than to single ones. Selecting the best figures, we find that Ångström's wave

* Thalen, Sur Spectre du Fer, Société Royale des Sciences d'Upsal, September, 1884, p. 25.

† From one grating only.

lengths must be multiplied by 1·00016 to agree with Bell, while the correction for Ångström's error of scale would be 1·000110.

It is impossible for me to give at present all the data on which my determinations rest, but I have given in Table I many of the coincidences as observed with several gratings, the number of single readings being given in the parenthesis over each set.

Table II gives the wave lengths as interpolated by the micrometer. It is scarcely possible that any error will be found (except accidental errors) of more than ·02, and from the agreement of the observations, I scarcely expect to make any changes in the final table of more than ·01, except in the extremities of the spectrum, where it may amount to ·03 in the region of the A and H lines. The wave lengths of weight greater than 1 will probably be found more exact than this. The lines can be identified on my new photograph of the spectrum down to 5790. Below this there is little trouble in finding the right ones. All maps of the spectrum, especially above F, are so imperfect that it is almost impossible to identify my lines upon them. The lines can only be properly identified by a power sufficient to clearly divide b_3 and b_4. Some of them are double and most of these have been marked, but as the table has been made for my own use, I have not been very careful to examine each line. This will, however, be finally done. Micrometric measures have now been made of nearly all the lines below *b* with a view of making a map of this region.

Table I gives the coincidences of the different orders of the spectra as observed with several concave gratings on both sides of the normal, the numbers in the brackets indicating the number of observations. The observations have been reduced as nearly as possible to what I consider the true wave length, the small difference from the numbers given in table II, being the variation of the observations from the mean value. The true way of reducing these observations would be to form a linear equation for each series and reduce by the method of least squares. A simpler way was, however, used and the relative wave length of the standard lines, marked S in table II, was obtained; however, some other observations were also included.

Table II gives the wave lengths reduced to Bell's value for the absolute wave length of the D line. These were obtained by micrometric measurement from the standards as described before. The weights are given in the first column and some of the lines, which were measured double, have also been marked. But the series has not yet been carefully examined for doubles.

The method is so much more accurate than by means of

angular measurement that the latter has little or no weight in comparison.

This table is to be used in connection with my photographic map of the normal spectrum to determine the error of the latter at any point. The map was made by placing the photograph in contact with the scale, which was the same for each order of spectrum, and enlarging the two together. In this way the map has no local irregularities, although the scale may be displaced slightly from its true position, and may be a little too long or short, although as far as I have tested it, it seems to have very little error of the latter sort. The scale was meant in all cases, except the ultra violet, to apply to Peirce's absolute value and so the correction is generally negative, as follows:

Approximate correction to the photographic map of the normal spectrum to reduce to latest absolute value.

Strip	3200 to 3330	Correction	−.05
"	3275 to 3530	"	−·05
"	3475 to 3730	"	−·02
"	3675 to 3930	"	−·10
"	3875 to 4130	"	−·16
"	4075 to 4330	"	−·04
"	4275 to 4530	"	−·08
"	4480 to 4735	"	−·10
"	4685 to 4940	"	−·18
"	4875 to 5130	"	−·14
"	5075 to 5330	"	−·15
"	5215 to 5595	"	about −·05
"	5415 to 5795	"	about −·04
"	3710 to 3910	"	−·20
"	3810 to 4000	"	−·14

It is to be noted that the third spectrum of the map runs into the second, so that it must not be used beyond wave length 3200, as it is mixed with the second in that region.

TABLE I.

Coincidences.

(2)	(8)	6439·222	(4)
7039·969	4691·516	4293·181	7240·868
7027·658	4690·260	(9)	4824·243
7023·676	5624·696	6439·222	4823·636
5269·656	5624·184	4293·181	7234·854
5270·448	(6)	(2)	7233·063
(6)	4508·402	4824·240	(6)
7039·963	4501·387	4823·640	4501·377
4222·336	5624·696	7184·701	6750·332
7027·627	5624·181	(4)	(4)
5270·429	4496·990	7247·569	4691·517
5269·647	4494·677	4824·249	7035 056
4215·627	(18)	4823·630	6027·665
7023·632	6430·993		7015·641

7015·256

(4)
4691·517
7027·675

(10)
4501·377
6759·308

(8)
4508·381
4504·921
4502·791
6752·830
4501·377
6750·306

(4)
6013·682
4508·407
6003·173
4501·377
4496·982
4494·652

(10)
4215 613
6322·820

(4)
6562·960
6564·341
4376·052

(4)
4222·309
4215·613
6322·817
6318·165
6278·255
6252·698
6246·451

(6)
6562·960
4376·041

(3)
4691·517
7023·706

(2)
4691·517
7027·655

(1) Phot.
5624·691
3754·63
3747·09

(1) Phot.
5914·32
3942·72

(1) Phot.
5914·32
3942·70

(1) Phot.
5890·12
5896·10
3926·12

(4)
6883·994
4590·051
4588·306

(2)
4823·638
4824·261
7233·103
7240·902

(2)
5288·632
6609·215
6593·992
6593·038
5270·419
5269·651
6567·645
6564·313
4376·050
5250·751
5250·329
6562·970
6569·353
6546·393
6495·119
6493·931
6462·760
5162·492
5159·171
6439·215
6430·984
6421·513
6420·090
5133·805
6411·776
5110·506
5109·754
5068·878
5060·191
5049·932
6522·833
6318·150
6265·256
6261·221

(1) Phot.
6024·2
6016·8
5948·7
3953·9
3950·4
5916·4
5914·3
3916·8
5862·5
5859·8
3897·5
5791·1
5788·1

(1) Phot.
4789·7
4789·4

4788·8
4754·1
3564·6
3549·9
4772·5
3545·2
3540·2
4691·5
4690·3

(14)
5162·394
6883·995

(6)
6594·016
6593·072
5270 427
5269 647
6569·348
6562·970
5250·325
5250·752
4376·032

(4)
6569·370
4924·889
4924·045
6562·965
6546·409
4903 419
4859·866
4861·428
6462·744
4824·255
4823·631

(6)
5914 323
5896·084
5890·125
4691·517
4690·266
5862·522
5859·751
4683·691

(6)
4376·039
5269·632
5270·420

(4)
4222·301
4215 613
5270·435
5269·654

(12)
5914·314
4222·325
4924·889
4924·052
4215·613
5896·083
5890·125
4903·411

(4)
4508·397
4501·380
5624·696
5624·180
4496·979
4494·647

(10)
4508·396
5405·901
4501·377
6750·299
4496·977
4494·660

(15)
4215·613
6322·848

(6)
5896·091
5890·124
4703·112
4691·517
4690·272
4683·694

(6)
5791·124
4824·255
4823·632
5788·064

(4)
5914·314
5896·086
5890·121
5862·514
5859·753
5857·613

(6)
6564·330
5270·430
5269·647

(8)
5068·880
6335·486
4222·330
5064·779
4215·613
5060·194
6322·842
6318·168

(4)
7027·671
5624·696
7035·107
7039·980

(6)
4891·523
5624·696
5624·184
4686·345
4678·971

(4)	5624·696	4508·417	(16)
5896·080	5624·198	4501·393	4222·328
4691·517	7027·657	(24)	5624·696
5862·506	7023·686	6322 825	5624·194
( )	(4)	5270·431	4215·612
7039·975	5270·431		
4691·532	6322·825		

TABLE II.

Wave Lengths of Standard Lines.

Wt.	W. L.	Wt.	W. L.	Wt.	W. L.
1	3169·4	S	4376·039	4	4978·712
1	3261·6	2	4391·089	2	4980·292
1	3347·9	2	4407·797	2	4981·836
1	3329·50	2	4447·848	2	4994·251
1	3406 50	S	4494·667	2	4999·626
1	3540·24	S*d*(?)	4496·984	2	5005·838
1	3545·31	1	4499·022	2	5006·239
1	3549·97	1	4499·267	3	5007·370
1	3564·64	S	4501·384	2	5014·350
1	3747·09	S	4508·400	3	5020·139
1	3754·63	2	4554·154	2	5036·029
1	3897·54	2	4571·214	3	5049·944
1	3916·82	2	4572·092	S	5060·188
1	3924·70	2	4578·663	S	5064·773
1	3925·38	4	4588·320	S	5068·879
1	3925·81	4	4590·055	2	5083·460
1	3926·15	2	4602·107	2	5090·897
2	3942 54	2	4611·376	2	5097·071
1	3950·45	2	4629 445	3	5105·663
1	3953·93	2	4630·218	4	5109·760
1	3984·08	2	4643·580	4	5110·502
1	3985·54	2	4668·230	2	5115·495
1	3987 000	S	4678·970	2	5121·730
1	4005·261	5	4683·683	2	5126·309
1	4035·764	S	4686·344	2	5127·468
2	4048·821	S	4690·262	4	5133·812
2	4055·626	S	4691·520	3*d*	5139·472
2	4073·837	4	4703·110	2	5141·845
3*d*	4083·748	2	4703·910	2*d*	5142·986
3	4107·578	2	4727·565	3	5146·612
3	4114·530	2	4754·159	3	5150·957
2	4157·893	2	4805·186	2	5154·157
2	4184·992	S	4823·630	2	5155·864
2	4199·190	S	4824·256	3	5159·171
S	4215·613	S	4859·864	6	5162·486
S	4222·323	S	4861·428†	2	5165·518
3	4254·452	2	4890·885	2*d*	5167·499‡
1	4267·974	1	4900·039	2*d*	5169·094§
4	4293·201	1	4900·237	3	5171·714
2*d*	4307·961*	S	4903·409	2	5172·795‖
2	4318·782	1	4907·869	3	5173·838
4*d*	4325·924	2	4919·111	3	5183·735¶
2	4337·143	3	4920·632	2*d*	5188·892
2	4343·304	S	4924·050	2	5193·071
3*d*	4352·865	S	4924·887	2	5198·819
2*d*(?)	4359·715	2	4934·181	3	5202·422
2	4369·887	4	4973·294	2	5204·646

* Fraunhofer's G. † Fraunhofer's F. ‡ Fraunhofer's b_4.
§ Fraunhofer's b_3 ‖ Fraunhofer's b_2. ¶ Fraunhofer's b.

Wt.	W. L.	Wt.	W. L.	Wt.	W. L.
4	5210·492	3	5544·073	2	5919·795
2	5215·277	3	5555·035	3	5930·339
2	5217·488	2	5569·772	2	5934·809
2	5225·617	1	5576·222	2	5946·130
2	5229·950	2	5582·120	4	5948·685
2	5233·047	2	5588·910	2	5951·710
2	5241·599	2*d*	5603·019	2	5955·106
S	5250·334	2	5615·451	2	5956·853
S	5250·759	2	5615·809	2	5975·508
2	5253·558	S	5624·181	3	5976·934
2	5261·815	S	5624·696‡	2	5984·977
S	5269·649*	2	5641·595	3	5987·214
S*d*	5270·429*	2	5645.751	S	6003·173
2*d*	5273·379	2	5655·645	2	6008·700
2	5276·138	3	5658·019	S	6013·682
2	5281·908	2	5662·679	4	6016·776
2	5283·747	2	5675·593	2*d*	6020·278
3	5288·640	2	5679·184	2	6021·948
3	5296·798	4	5682·894	4	6024·207
2	5300·843	2	5688·370	4	6042·241
2	5307 478	2	5701·708	3	6056·153
3*d*	5316·803†	2	5709·565	6	6065·635
2	5324·311	2	5709·700	6	6078·635
2	5333·038	3	5715·244	4	6079·146
3	5353·530	4	5731·909	3	6102·864
2	5361·752	2	5741·994	1	6103·346
1	5362 970	3	5752·188	2	6108·262
2	5367 600	3	5753·278	2	6111·206
2	5370 093	2	5754·819	2	6116·345
2	5371·622	3	5763·153	5	6122·357
2	5379·704	2	5772·299	2	6136·760
4	5383·497	3	5775·235	3	6141·882
2	5389·611	2	5782 285	4	6162·319
2	5393·298	2	5784·015	2	6169·699
2	5397·268	S	5788·075	2	6173·477
S	5405·914	S	5791·137	2	6176·943
2	5415·341	2	5798·330	2	6180·337
2	5424·203	2	5809 357	3	6191·324
2	5434·656	2	5816·504	4	6191·695
2	5447·046	3	5853·838	5	6200·455
3*d*	5455·682	4	5857·606	3	6213·569
2	5462·666	6	5859·741	4	6219·420
2	5463·090	7	5862·511	4	6230·876
3	5463·408	2	5883·971	2	6237·452
3	5466·521	3	5889·804	3	6246·460
2	5477·040	S	5890·125 D_2	3	6252·706
3	5497·660	3	5893·026	2	6256·500
2	5501·609	S	5896·080 D_1	3	6261·234
2	5506·920	2	5898·327	5	6265·271
2	5513·122	2	5901·630	6	6270·370
3	5528·560	3	5905·820	5	6278·225
2	5534·990	S*d*	5914·319	4	6281·315
2	5543·339	3	5916·409	1	6289·542

* Fraunhofer's E. † Kirchhoff's 1474.

‡ Peirce's standard, given by him 5624·825 (Amer. Jour. of Science) later corrected by him to 5624·86 and finally corrected by Rowland & Bell for error of ruling of grating and of standard to 5624·66. The latter can be considered as very near to what the final corrected value of Peirce will be, though it may be even so high as 5624·76.

Wt.	W. L.
2	6293·077
2	6296·066
2	6314·798
S	6318·160
S	6322·830
8	6335·479
8	6336·968
2	6344·297
5	6355·184
4	6358·834
2	6380·889
5	6393·751
2	6400·453
5	6408·163
6	6411·793
4	6420·103
7	6421·498
6	6430·993
5	6439·224
2	6449·951
7*d*	6462·762
2	6471·805
2	6480·198
4	6482·031
5	6493·921
5	6495·127
4	6499·896
2	6516·2·6
3	6518·514
4	6532·496
4	6534·090
5	6546·400
2	6552·758
S	6562·965*
S	6564·338
7	6569 360
2	6572·245
2*d*	6575·090
2	6592·725
6	6593·068
8	6594·016
5	6609·253
2	6633·898
6	6643·787
2	6663·601
6	6678·141
5	6703·719
5	6705·262
4	6717·833
4	6722·005
3	6726·835
S	6750·325
4	6752·876
5	6767·945
5	6772·479
2	6787·051
2	6807·007
4	6810·432
4	6828·770
2	6841·518
3	6855 348
3	6867.382†
3	6867·717
2	6870·123
4	6875·742
2	6876·879
2	6877·797
6	6879·212
6	6880·102
10	6883·992‡
6	6885·925
6	6886·898
1	6896·211
2	6897·103
2	6901·032
2	6909·597
4	6919·160
1	6923·488
4	6924·340
2*d*	6929·687
4	6947·685
4	6956·609
4	6959·634
5	6961·437
2	6978·586
6	6986·755
2	6989·172
3	6999·104
2	7006·069
2	7011·481
3	7015·253
3	7015·639
4	7016 616
S	7023·675
S	7027·659
S	7035·083
2	7038·398
S	7039·968
1	7090·612
1	7122·431
1	7147·893
1	7148·276
1	7168·134
2	7176·279
1	7184·401
4	7184·705
2	7186·470
1	7194·805
1	7199·689
1	7200·673
1	7216·693
1	7219·282
2	7223·830
1	7227·686
1	7232·419
S	7233·092
S	7234·868
S	7240·879
2	7243·800
S	7247·590
1	7264·770
1	7265·750
2	7273·133
1	7287·590
1	7289·844
1	7290·621
2	7299·993
2	7304·382
2	7318·678
1	7331·101
2	7335.532
1	7442·574
2	7445.941
2	7495.248
1	7511.188
2	7545·817
2	7593·975§
2	7621·183‖
2	7623·425
2	7624·737
1	7627·259
1	7628·605
1	7659·550
1	7660·679
1*d*	7665·683
1*d*	7671.412

* Fraunhofer's C.
† First line in what may be called the head of Fraunhofer's B.
‡ Single line between what may be called the head and tail of B.
§ Edge of what may be called the head of A.
‖ Single line between the head and tail of A.

ART. XXII.—*The Norites of the "Cortlandt Series" on the Hudson River near Peekskill, N. Y.;* by G. H. WILLIAMS.

[Continued from page 144.]

3. *Mica Norite.*

The purest types of this rock are to be found in the eastern part of Cortlandt Township, along the road leading from Montrose Station (Munger's Corners) to Montrose Point on the river. Nos. 40, 41, 49, 51 and 52 and a slide marked Mt. 9 in Prof. Dana's collection were obtained along the section described in detail in Prof. Dana's paper and adduced by him as evidence of the metamorphic origin of the rocks from sedimentary deposits.* The microscopic study of these slides is therefore important with reference to the light which it may throw upon this question.

This section, which occurs just at the residence of Mr. Butler (1883), has been called by the writer the "Butler Section" (see above). Professor Dana gives a profile of it and says (p. 218): "*It consists mainly of noryte and augite-noryte, but with some hornblendyte and noryte-gneiss and has distinct planes of bedding in several places, all of which are conformable to one another.* . . . . This ledge, although made up of massive noryte and augite-noryte, bears thus positive evidence of its having once had bedding throughout, and affords thereby a demonstration that its noryte is of metamorphic origin and that the associated beds comprised also the limestone of the region."†

The specimens 41 (*c*), 47 (*g*), 49 (*e*), 51 (*c*)‡ and 52 are identical in structure and composition, except in so far as they contain different proportions of biotite. They consist of aggregates of magnetite, hypersthene and biotite which are curiously bent and twisted around larger areas of feldspar, so as to form a pronounced "microflaser" structure. The feldspar too shows to a remarkable degree both mechanical and optical deformation. Its crystals are bent or broken; secondary twinning lamellæ have been abundantly produced by strain, and the extinction is very uneven. Moreover portions of the areas are frequently seen to be broken up into the peculiar mosaic which both Lehmann§ and Lossen‖ have shown to be a characteristic result of pressure. Then again garnet, a mineral well known to be the product of dislocation metamorphism in rocks, is here abundant in some of the most schistose bands, notably Nos. 51 and 52.

* This Journal, September, 1880, xx, p. 218.

† The italics are those of Professor Dana.

‡ These letters in parentheses are those used by Professor Dana to designate particular beds in his section.

§ Ueber die Entstehung der altkrystallinen Schiefergesteine. Bonn, 1884.

‖ Jahrbuch der kön. preuss. geolog. Landesanstalt für 1883. Berlin, 1884.

The writer has already described another rock from this section* (a peridotite, No. 54), occurring in the bed marked by Professor Dana "*a*," as showing in a marked degree the effects of pressure, while No. 48, from his band "*f*," is still more remarkable in this respect. This rock was once a gabbro, like that to be described in the sequel as occurring at Munger's Corners (No. 42). At present it is highly altered both structurally and mineralogically. The diallage is largely changed to hornblende and is drawn out into long lenticular patches. The feldspar is mostly broken up into a mosaic which bends around the pyroxene, producing a fine gneissic structure. In fact this rock is almost identical with some of the more altered "Flaser gabbros" of Saxony, which Professor Lehmann† has so conclusively shown to have resulted from the action of pressure upon massive rocks.

The hornblende norites (Nos. 50*a* and 50*b*) from this section mentioned above are wholly massive and show no internal evidence of having been subjected to pressure.

A careful study of the rocks of this interesting section, both in the field and with the microscope, has convinced the writer that they offer an unusually plain and instructive instance of the *metamorphism of eruptive rocks by pressure. The evidence of bedding*, seen in the cleavage and parallel arrangement of the constituents, *instead of being an indication of original sedimentation, is a secondary feature.* The action of the pressure was here so slight that original structure is not wholly changed, as is more usually the case; but the alteration has only taken place along certain planes which allow the tracing of transitions into the original, unaltered and still prevailing form of the rock.

No. 6*a* from near Cruger's Station, is a remarkable variety of mica-norite, in which the hypersthene is segregated into irregular patches. Outside of these the rock is a typical mica-diorite composed of plagioclase, biotite, magnetite and apatite, together with a considerable amount of garnet which is a secondary crystallization. Within the segregated areas the space is almost wholly occupied by hypersthene, which exhibits in a striking manner its alteration to secondary fibrous hornblende.

4. *Augite Norite or Hyperite.*

Professor Dana has communicated the following analyses, by Mr. M. D. Munn, of a specimen of augite-bearing norite from the northern part of Montrose Point on the Hudson River.‡

* This Journal, Jan., 1886, xxxi, p. 39.
† l. c., p. 190.
‡ This Journal, Aug., 1881, xxxii, p. 104.

	I.	II.	Mean.
SiO_2	55·28	55·40	55·34
Al_2O_3	16·31	16·44	16·37
Fe_2O_3	0·69	0·85	0·77
FeO	7·57	7·51	7·54
MnO	0·40	0·39	0·40
MgO	5·05	5·05	5·05
CaO	7·52	7·49	7·51
Na_2O	4·10	4·03	4·06
K_2O	2·05	2·00	2·03
H_2O	0·58	0·58	0·58
	99·55	99·73	99·65

Professor Dana describes this rock as an augite-norite containing about equal proportions of hypersthene and augite. A thin section in his collection marked (Mt. 20) the writer supposes to be the one alluded to in his description as it is the only one from this locality. This is, however, almost a typical norite with a large proportion of the usual reddish-brown feldspar, very typical hypersthene, and only occasional individuals of a green fibrous diallage and dark brown biotite. The percentage of lime in the analysis, after deducting what is necessary for the feldspar also indicates but a small proportion of augite. This section also shows considerable unstriated feldspar, which, from the analogy of No. 43 and the percentage of potash found in the analysis, may safely be assigned to orthoclase. A study of this section indicates that this analysis is very representative of the average norite of the Cortlandt Series.

A more typical augite-norite or hyperite is to be found in specimen No. 69, of the Johns Hopkins University collection, which was collected from the same locality as the above. Here the proportion of both augite and biotite is considerably greater than in Professor Dana's section. This slide is especially interesting from the fact that it exhibits, in both the hypersthene and augite, inclusions which the writer would without hesitation consider as secondary and identical as those in the Scottish rocks which Professor Judd rightly ascribes to schillerization. Side by side with these, however, are other inclusions in the feldspar which, like those above described, are original.

No. 105 in the University collection from the road from Centerville to Verplanck, and a section, marked J, in Professor Dana's collection from Craig's place, one mile S.E. of Peekskill are also admirable examples of the augite-norite. Both contain nearly as much augite as hypersthene. The former mineral is distinguished from the latter by its green color, the entire absence of pleochroism, its highly inclined extinction-angle, the frequency with which it forms twins, and its com-

parative freedom from inclusions. These are not altogether wanting, but consist almost wholly of small plates of biotite or grains of magnetite, presenting, both in their number and irregular arrangement, a contrast to the characteristic red plates of the hypersthene. Both of these slides contain considerable biotite in addition to the augite. This mineral, as well as the feldspar, exhibits in a beautiful manner the effects of pressure.

5. *Pyroxenite.*

Very interesting and comparatively coarse-grained rocks composed wholly of hypersthene and diallage or augite may be regarded as a modification of the type last described, due to the disappearance of the feldspar. They are quite abundant in the eastern part of the township near the emery mines and are represented by Nos. 127, 129, 131 and 132 in the Johns Hopkins University collection. Such rocks also occur on the northern half of Montrose Point, but here they carry more or less brown hornblende and are intimately related to the hornblendites which are the prevailing rock in that locality and which will be described later.

Diallage-hypersthene aggregates have recently been found by the writer, associated with the hypersthene-gabbros of Baltimore and Harford Counties, Md., which are quite analogous to those occurring in the Cortlandt Series.*

The Iron ore and Emery in the Cortlandt Norite.

The deposits of magnetic iron ore and emery mentioned in Professor Dana's paper† as occurring in the massive rocks of the Cortlandt Series, although of but little practical importance, possess considerable scientific interest. The veins, which appear to be segregations in the norite, have been opened north and northeast of Cruger's Station only for iron ore, while quite similar deposits in the southeastern part of the township, are still worked to some extent for emery.‡ The ore is heavy and black, but does not turn out as rich as would be expected from its appearance. A microscopic examination of it shows that it is largely composed of a dark green mineral in which octahedral crystals of magnetite are imbedded. Professor Dana considered this mineral to be chlorite, but a more careful examination shows it to be the iron-magnesian spinel, *pleonaste*. The action of chlorite upon polarized light, as is well known, is extremely feeble and so it was not unnatural to mistake for it

* Bulletin of the U. S. Geol. Surv., No. 28, p. 55.

† This Journal, September, 1880, xx, p. 199–200.

‡ The emery mill at Peekskill owes its origin to the discovery of these deposits, although at present it procures its raw material almost exclusively from Asia Minor.

an isotropic mineral, like spinel. In the massive ore this mineral forms an aggregate of interlocking grains, but in the adjoining rock it is disseminated in small octahedral crystals as in section No. 6*a* described above. It was isolated from a specimen of iron ore collected near Cruger's Station and analyzed by Mr. W. S. Bayley.*

In the eastern and southeastern parts of the norite region similar deposits of pleonaste occur in great number, and frequently contain more or less corundum and fibrolite.

The Westchester Co. pleonaste is remarkable for its small proportion of magnesia. The eight analyses of this mineral given in Dana's System of Mineralogy (p. 148) have from 13 to 26 per cent MgO. The specimen which comes nearest in composition to the Cortlandt mineral is one from Tunaberg in Sweden, in which Erdmann found Al_2O_3 62·95, FeO 23·46, MgO 13·03.† Still even here the amount of magnesia is considerably greater than in the mineral analyzed by Mr. Bayley. In this respect the Cortlandt pleonaste approaches the pure iron spinel (FeO,Al_2O_3) which Zippe, in 1839, named Hercynite.‡ This was analyzed in 1845 by B. Quadrat, who found that it contained

Al_2O_3 61·17, FeO 35·67, MgO 2·92.§

This mineral occurs in black masses near the villages of Natschetin and Hoslau, nor far distant from the town of Ronsperg, at the eastern edge of the Bohemian Forest. (Lat. "*Silvia Hercynia*," Pliny, whence Zippe's name). Quadrat states that it is only found in loose blocks in the soil, but von Hochstetter says that it occurs in position, as "a member of the Archæan Series, between amphibolite and amphibole-schist."‖ The Bohemian hercynite was first microscopically studied by H. Fischer, who discovered in the spinel aggregate what he considered to be magnetite, quartz and hematite.¶ E. Kalkowsky, subsequently showed the supposed quartz to be corundum, and the hematite, iron-hydroxide.** Certain very thin, dark gray plates which are frequently interpolated in the hercynite are referred by Kalkowsky to ilmenite. A microscopic section of the Ronsperg hercynite in the possession of the writer, contains

* The exact results of this analysis were unfortunately lost, but it is definitely remembered that the mineral was found to contain only alumina, ferrous iron and magnesia; and that the latter constituted slightly over 9 per cent of the whole.

† Ak. H. Stockh., 1848.

‡ Verh. der Gesellsch. des Vaterländ. Museums, 1839.

§ Annalen der Ch. und Ph., lv, p. 357. 1845.

‖ Geog. Studien aus dem Böhmerwald. Jahrbuch der k.k. geologischen Reichsanstalt, 1856, p. 785.

¶ Kritisch micromineralogische Studien, Freiburg, 1869, p. 18, II. Fortsetzung, 1873, p. 88.

** Zeitschrift der deutschen geologischen Gesellschaft, 1881, p. 536.

magnetite, limonite, ilmenite, considerable light brown biotite and a colorless mineral which may once have been corundum, but which now shows only a very fine aggregate polarization.

The Cortlandt ore, when examined under the microscope, exactly resembles the Bohemian hercynite. In the purest specimens, there is only the aggregate of bright green grains mixed with more or less magnetite. These grains are always of a much lighter color in contact with the magnetite. They contain no ilmenite plates, like the Bohemian mineral, but are full of irregular shreds and dots of magnetite. (Nos. 134, 143 and 144 from the eastern part of the township.) Other specimens (No. 133 from Wm. Haight's farm and I of Prof. Dana's collection, from 1 mile northeast of Colabaugh Pond) contain more or less corundum scattered through them.* Sometimes this mineral is associated with fibrolite; and, in the section of Prof. Dana's collection marked Cb4, from the Iron Mine south of the road south of Summer Hill, only fibrolite occurs with the pleonaste. This is interesting in connection with the intimate association discovered by Kalkowsky between the hercynite and fibrolite in the Saxon granulites.†

The spinel at the Cruger iron mines is quite like that in the eastern part of the township except that it is less pure. It occurs as veins in a typical norite into which it passes by gradual transitions. Even the most compact specimens of the ore contain the norite minerals, hypersthene, feldspar, biotite, and garnet, mixed with it in greater or less quantity. At this locality no corundum or sillimanite was observed.

Quadrat remarked in 1845 that on account of its great hardness (7·5–8), the Ronsperg hercynite was employed, in the region near where it was found, as an abrasive agent.‡ The admixture of true corundum, of course, very much increases its value for such purposes, and it is this which accounts for the opening of numerous emery mines in the eastern portion of Cortlandt township.

According to the late Dr. J. Lawrence Smith, large deposits of corundum or true emery occur either associated with magnetite on the contact between crystalline limestone and mica-schist (as in Asia Minor) or in connection with serpentine (as in North Carolina).§ Its association with spinel in massive rocks, where it is probably a product of contact metamorphism

* The writer is under obligations to Professor A. H. Chester of Hamilton College for several interesting specimens of corundum altered to hercynite. They came from India and have been described by Genth, Proc. Am. Phil. Soc. Philadelphia, Sept., 1873.

† Zeitschrift der deutschen geologischen Gesellschaft, 1881, p. 537.

‡ l. c., p. 357.

§ Memoir on Emery, this Journal, 1850, p. 354. Annales des Mines, 1850, p. 259. Original Researches, 1884, p. 75.

like the fibrolite, is exceptional, but by no means unprecedented, as may be seen from the above description of the Ronsperg hercynite. In the Cortlandt deposits the distribution of the corundum is so irregular as to seriously interfere with its practical value. Specimens in which it is comparatively abundant are not to be distinguished, except under the microscope, from those which are entirely free from it. How far this is true may be judged from the fact that the purest specimens of pleonaste which the writer obtained anywhere in Cortlandt township were taken from the pile of "emery ore" in the yard of the Peekskill emery mill. This so reduces the grade of the Cortland product as to practically rule it out of the market.

The following seven analyses of the Cortlandt ore were made in 1880, for the New York Emery Co., of Peekskill, by Prof. Th. Egleston of the Columbia College School of Mines. They are here published for the first time with the permission of their author.

	I.	II.	III.	IV.	V.	VI.	VII.
Al_2O_3	31·93	40·77	37·78	37·43	36·49	41·66	46·53
Fe_2O_3	18·19	18·37	24·35	21·17	21·36	23·71	32·31
MgO	7·41	6·73	7·92	7·20	8·39	7·91	9·43
Magnetic iron	34·20	32·01	17·37	19·81	22·77	14·76	8·98
Siliceous residue	6·42	1·04	11·19	13·14	10·08	11·48	2·42
TiO_2	1·12	1·08	0·62	0·65	0·67	0·54	0·51
Sulphur	0·04	0·04	0·02	0·02	0·02	0·01	0·01
Phosphorus	trace	trace	trace	trace	trace	trace	trace
Total	99·31	100·04	99·25	99·42	99·78	100·07	100·19

If from these analyses all the components except the alumina, magnesia and iron be deducted, and if these be calculated in proportions of 100 after the ferric iron has been reduced to its equivalent per cent of ferrous iron, we shall have:

	I.	II.	III.	IV.	V.	VI.	VII.	Mean.
Al_2O_3	53·63	60.00	51·94	54·92	53·18	54·88	50·65	54·17
FeO	33·92	30·05	37·18	34·52	34·59	34·70	39·08	34·87
MgO	12·45	9·95	10·88	10·56	12·23	10·42	10·28	10·96
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

A glance at these analyses is sufficient to show that a very large proportion, if not all, of the samples consisted of pleonaste. Still, the microscope discloses the presence of true corundum in many specimens, although its amount is very variable.

Section H of Prof. Dana's collection from 1 mile northeast of Colabaugh Pond, consists of magnetite and pleonaste mixed with about an equal quantity of colorless corundum. This is in good sized grains ($\frac{1}{2}$-$\frac{2}{8}$mm in diameter) with a high refractive index and often shows a sharp hexagonal section. These exhibit between crossed nicols, very brilliant interference colors. Frequently, however, they appear to be somewhat altered and then exhibit a gray tone with aggregate polarization. These corundum crystals contain inclusions in great quantity. These appear to be either magnetite in small rods or dots or reddish translucent plates of iron oxide. They are always massed together in the center of the crystal, frequently in such abundance as to render this portion quite opaque.

No. 126, from near Travers' farm in the eastern part of Cortlandt township, is quite like the preceding, except that the corundum is much more abundant and present in individuals of much smaller size ($\frac{1}{6}$-$\frac{1}{8}$mm in diameter.) The distribution of the inclusions is quite like that in the specimen last described.

In some of the sections, the corundum is seen to have a deep blue color, and then to exhibit its characteristic dichroism. This is most notably the case in specimens taken from the Lombard mine, just north of Colabaugh Pond. This locality is represented by Nos. 136 and 137 of the University collection and by section A, belonging to Prof. Dana. These are seen under the microscope to be composed of an aggregation of the three minerals, fibrolite, corundum and magnetite. The first is present in long, colorless needles, showing the characteristic cleavage, transverse parting, parallel extinction, and brilliant interference colors of this species. They have their longest axes approximately parallel thus producing a somewhat schistose structure. The corundum is present in rather stout crystals, with a sharp hexagonal outline in cross-section. Such sections have in every position a uniform deep blue color, while those nearly parallel to the vertical axis have this color when their lateral axis is parallel to the principal section of the polarizer and a light greenish yellow tinge when brought into a position at right angles to this. The pleochroism is therefore:

$$\left\{\begin{array}{l} \text{E=light greenish yellow} \\ \text{O=dark blue} \end{array}\right.$$

and the absorption O>E. The hexagonal sections, when examined in converged polarized light, show a uniaxial interference figure and negative double refraction. All of these characters agree fully with corundum; and the examinations, for comparison, of sections of typical emery, from Samos, Naxos, Smyrna and Gumuch-dagh in Asia Minor and from Chester, Mass., leaves little doubt of the identity of these with the Cortlandt mineral.

The results of the optical examination are fully in accord with a series of chemical tests which Dr. C. Pigot, assistant in the Chemical Laboratory of the Johns Hopkins University, kindly made for me. The powder of the mineral, which had been separated from the fibrolite by the boro-tungstate of cadmium solution and from the magnetite by boiling it in hydrochloric acid, was found not to be attacked by any acids. It is very difficultly fusible with sodium carbonate but fuses readily with acid potassium sulphate or acid sodium sulphate. In the solution thus obtained the presence of nothing except alumina and iron could be detected. The only unusual property of this corundum is a lower specific gravity than was expected. This is probably due to incipient alteration, which can be easily seen under the microscope, and is another cause that would tend to materially diminish the value of the Westchester Co. emery.

In a succeeding paper the writer hopes to describe the remaining members of the Cortlandt Series (gabbros and diorites) and to point out the metamorphosing effect which the massive rocks have exercised upon the surrounding schists and limestones, as well as other proofs of their undoubted eruptive character.

Petrographical Laboratory of the Johns Hopkins University,
Baltimore, December, 1886.

ART. XXIII.—*Natural solutions of Cinnabar, Gold and associated sulphides;* by GEORGE F. BECKER.

IN the course of investigations on the geology of the quicksilver deposits of the Pacific slope I have taken up the question of the state of combination in which quicksilver is dissolved in natural waters. Pyrite or marcasite almost invariably accompanies cinnabar, gold is known to be associated with cinnabar in a considerable number of cases, copper sulphides or sulphosalts are also not infrequent in quicksilver mines, and sulphides of arsenic and antimony are known to occur in a similar association. Zincblende too has been found with cinnabar. The solubility of these substances has been incidentally examined. In performing the experiments I had the assistance of Dr. W. H. Melville, who also made all the quantitative analyses involved. The results obtained seem interesting enough to justify their publication, in an abbreviated form, in advance of the monograph of which they will form a part. They also possess some value from a purely chemical point of view, and may interest readers of this Journal who are not geologists.

The waters of Steamboat Springs are now depositing gold, probably in the metallic state; sulphides of arsenic, antimony and mercury; sulphides or sulpho-salts of silver, lead, copper and zinc; iron oxide and possibly also iron sulphides; manganese, nickel and cobalt compounds, with a variety of earthy minerals. The sulphides which are most abundant in the deposits are found in solution in the water itself, while the remaining metallic compounds occur in deposits from springs now active, or which have been active within a few years. These springs are thus actually adding to the ore deposit of the locality, which has been worked for quicksilver in former years and would again be exploited were the price of this metal to return to the figure at which it stood a few years since. At Sulphur Bank also there is reason to suppose that ore deposition is still in progress, though the opportunities for determining this point are greatly inferior to those presented at Steamboat Springs. The waters of the two localities are closely analogous. Both contain sodium carbonate, sodium chloride, sulphur in one or more forms and borax as principal constituents, and both are extremely hot, those at Steamboat Springs in some cases reaching the boiling point. In attempting to determine in what forms the ores enumerated can be held in solution in such waters, it is manifestly expedient to begin by studying the simplest possible solutions of the sulphides and particularly of cinnabar.*

Solubility of HgS *in mixtures of* Na^2S *and* NaOH.—A series of experiments were made in my laboratory with a view of testing

* *Previous investigation.*—The solubility of mercuric sulphide in alkaline compounds containing sulphur has long been recognized by experimental and industrial chemists. This fact is the foundation of the methods of preparation of vermilion in the wet way, first described by G. S. C. Kirchoff in 1799 (Scheerer's Allgem. Journ. der Chem., vol. ii, p. 290). In 1829, C. Brunner (Pogg. Ann., vol. xv, p. 593) discovered the double soluble salt $HgS, K^2S, +5H^2O$. Later Dr. Rheinhardt Weber (Pogg. Ann., 1856, vol. xcvii, p. 76), reëxamined the properties and formation of this salt, which he found could exist only in the presence of free caustic alkali. In opposition to Prof. Stein, Dr. Weber is extremely positive in his statements that mercuric sulphide is entirely insoluble either in the simple sulphides of sodium and potassium, or in the sulphydrates of these metals, excepting in the presence of free hydrates. Dr. Weber's solvent was not, as he evidently supposes, a mixture of hydrate and sulphydrate but of simple sulphide and sulphydrate.

In 1864, Mr. C. T. Barfoed (Journ. für prakt. Chemie, 1864, vol. xciii, p. 230) investigated the behavior of mercuric sulphide to sodium sulphides. He, like Dr. Weber, found the metallic sulphide wholly insoluble in the sulphydrate, but soluble in the simple sulphide, and in mixtures of the latter either with the sulphydrate or with the hydrate. He insists that the necessary and sufficient condition for the solubility of mercuric sulphide is the presence of sodic monosulphide.

The assertion is frequently made in chemical writings (for example Graham-Otto, 5th Ed., part 3, vol. ii, p. 1119) in spite of the result obtained by Weber and by Barfoed that mercuric sulphide is soluble in sodic sulphydrate. In 1876, Mr. M. C. Méhu (Russian Journ. of Pharm., reported in Jahresbericht der Chemie, 1876, p. 282), examined the soluble crystalline mercury-sodium salt corresponding to Brun-

the relative effect of the quantity of sodium sulphide and sodium hydrate on the quantity of mercuric sulphide which a given mixture of the solvents would take up. It is almost impossible to make experiments of this kind with the same accuracy which can easily be attained in precipitations because, if one or more drops of either fluid reagent is added to a mass consisting of mercuric sulphide partially dissolved in the menstruum, it is not practicable to say how long a time will elapse before the additional drop will have become saturated. Approximate results are however readily obtained, and these appear in the present case to be sufficient.

It was found that, provided a small quantity of free hydrate exists in the mixture, the solubility of HgS depends solely upon the quantity of Na^2S in the solution. The average of fourteen experiments made with varying proporsitions of sodic hydrate gives 1HgS to 2·03 Na^2S. From the nature of the experiments a slight excess in the quantity of solvent employed is to be expected. One experiment was made by mixing mercuric sulphide and sodic sulphide in the proportion of two molecules of the latter to one of the former, and adding a few drops of caustic soda. A mere trace of mercuric sulphide remained undissolved, and this completely disappeared on the addition of a single drop of a solution of sodic sulphide, so that less than one drop completed the solution.

Chemists of course regard cases of solution such as that under discussion as due to the genesis of soluble double salts, which are formed according to ordinary laws of composition. The

ner's potassium compound. He found mercuric sulphide insoluble in sodic hydrate or in the simple sulphide of sodium, but highly soluble in mixtures.

Alkaline pentasulphides convert amorphous quicksilver sulphide digested with them into cinnabar (Gmelin-Kraut, Handbuch der Chemie, vol. iii, p. 756, where many references may be found), and this process implies a certain degree of solubility. Mr. Barfoed, however, found mercuric sulphide insoluble at ordinary pressures in sodium sulphydrate to which sulphur had been added, and the solubility, in the pentasulphide is probably slight. The conversion of the black sulphide into the red, does not appear to imply more than a mere trace of solubility, for Messrs. H. Sainte-Claire Deville and Debray produced rhombic crystals of cinnabar by heating precipitated sulphide with chlorhydric acid to 100° C. in a closed tube (Fouqué and Michael-Lévy, Syuthése des Min. et des Roches, p. 313). No statement is made in the account of this experiment of any means being employed to produce any great pressure. Mr. S. B. Christy (this Journal, vol. xvii, 1879, p. 453) found that at pressures of from 150 to 500 pounds per square inch and temperatures of from 180° to 250° various liquids heated with precipitated mercuric sulphide convert it into vermilion. He experimented with polysulphides of potassium, potassic sulphydrate, acid sodic carbonate charged with sulphydric acid, and a spring water containing acid sodic carbonate which he charged with sulphydric acid. He reached no conclusion as to the state of combination of the mercury in solution. The fact that glass is greatly attacked at high pressures and temperatures by alkaline solutions of course leaves many possibilities open. Prof. R. Wagner (Journal für prakt. Chemie, vol. xcviii, 1866, p. 23), has shown that mercuric sulphide is soluble in barium sulphide, and Prof. Roth (Allgem. u. chem. Geol., vol. i, p. 264) thinks it probable that calcium sulphide possesses a similar power.

above experiments show that this soluble double salt can be represented only in the formula $HgS, 2Na^2S$. The soluble mixture given by Méhu answers to $HgS+2{\cdot}07\ Na^2S$ and is thus, so far as it goes, confirmatory of the above experiments.

Solubility of HgS *in* Na^2S.—The most carefully prepared solutions of sodium sulphide dissolve mercuric sulphide freely. This statement is directly contrary to that which some of the chemists referred to have made, and it would be a rash one if the evidence to be adduced for it depended simply upon bringing solutions of sodic sulphide into contact with mercuric sulphide; for it is impossible to make certain that there is no trace of free caustic alkali or of sulphydrate in a solution of sodic sulphide, however closely its analysis may correspond to its theoretical composition. If, however, a solution of sodic sulphide containing sodic hydrate is treated with hydrogen sulphide, it is gradually converted into sodic sulphydrate and passes through a point at which the only compound present is the monosulphide. If mercuric sulphide is dissolved in a mixture of sodic sulphide and caustic soda, and the clear filtrate is treated with hydrogen sulphide, the mercuric sulphide begins to be precipitated when very little free caustic alkali is left, and is continuously precipitated until the entire amount of sodium present is converted into sulphydrate. The purest preparations of Na^2S which we have been able to make, dissolve mercuric sulphide less freely than mixtures of sodic sulphide and sulphydrate. Different preparations, however, shown by most careful analysis to correspond very accurately to the formula Na^2S, give somewhat different results, possibly indicating a minute variation from absolute purity. It does not seem *a priori* improbable, that the soluble salt when the sodic sulphide is absolutely pure is $HgS, 3Na^2S$; and one of our preparations gave almost exactly this result. It may also be that mixtures of $HgS, 2Na^2S$, and $HgS, 4Na^2S$ are formed in proportions varying with other conditions than the purity of the sodium sulphide, such as temperature and concentration.

Insolubility of HgS *in cold* NaHS.—Repeated experiments and analyses undertaken during this investigation have shown that mercuric sulphide is totally insoluble in sodium sulphydrate at ordinary temperatures, and that any preparation of this compound which will dissolve a trace of mercuric sulphide can be shown by analysis to fall short of complete saturation. A long time and an enormous quantity of hydrogen sulphide are required to completely saturate even a small amount of caustic soda with sulphur. As already mentioned, both Weber and Barfoed were aware of the insolubility of mercuric sulphide in sodium sulphydrate at ordinary temperatures. It will be seen later that the behavior of these compounds varies with the tem-

perature. If mercuric sulphide is left in contact with cold sodic sulphydrate for twenty four hours, just a trace of mercury goes into solution. This is due to the spontaneous loss of hydrogen sulphide which the sulphydrate is well known to undergo.

The absolute want of power of a preparation of sodic sulphydrate to dissolve a trace of mercuric sulphide is perhaps the best known test of its freedom from the alkaline monosulphide. This test does not show the absence of polysulphides, however, for we have frequently found mercuric sulphide totally insoluble in solutions of sodic sulphydrate, which possessed a yellow color, and which were proved by analysis to contain an excess of sulphur. This corresponds to Barfoed's observation. The occurrence of alkaline polysulphides in nature, excepting near the surface of the earth, seems so improbable, that I have undertaken no investigations of the conditions under which they dissolve mercuric sulphide.

Solubility of HgS *in mixtures of* Na^2S *and* NaHS.—For the purpose of determining the character of solutions of mercuric sulphide in mixtures of sodium sulphide and sulphydrate, clear solutions of mercuric sulphide in sodium sulphide and sodium hydrate were made, all the reagents being carefully prepared for the purpose, and sulphuretted hydrogen was passed through the solution until a large permanent precipitate of mercuric sulphide formed. The mass was then filtered, and of course the filtrate represented an absolutely saturated solution of mercuric sulphide in a mixture of sodic sulphide and sulphydrate. A portion of this solution was analyzed. The remainder was treated further with hydrogen sulphide, the precipitation being arrested before the separation of mercuric sulphide was completed, and the second filtrate, representing a second saturated solution of the metallic sulphide in a mixture of alkaline sulphide and sulphydrates, but one containing much less mercuric sulphide, was also analyzed.

These analyses, which formed the conclusion of a tedious series of experiments, show beyond any reasonable doubt that there is a compound HgS, $4Na^2S$ which is soluble in the presence of Na^2S, H^2S and which is decomposed by hydrogen sulphide in the presence of the sulphydrate by the reaction,

$$HgS,\ 4Na^2S + 4H^2S = HgS + 4Na^2S,\ H^2S.$$

Conclusion from the experiments.—It appears from the above that there are at least three double salts of the form HgS, $n$$Na^2S$, where n may be either 1, 2 or 4 and, judging from the analogy of the potassium compounds, there is probably also a compound of this group where n is $\frac{1}{2}$. The possibility of a case where n is 3 has also been adverted to. Thus mercuric sulphide readily enters into combination with sodic sulphide in various propor-

tions, while all the best known soluble compounds of mercuric sulphide and sodium have the same general formula. The presence of carbonates of the alkalies is also known, especially from Méhu's results, to be compatible with the existence of these compounds. The question therefore arises whether such double sulphides may not exist in natural waters.

Possible existence of Na^2S *in natural waters.*—This question resolves itself into two. It is to be considered whether Na^2S may exist in natural waters as such. In that case such waters must dissolve mercuric sulphide. It is also possible that alkaline monosulphides cannot exist as such in these waters, but that the affinity of sodic sulphide and mercuric sulphide is sufficient to overcome the obstacles to the formation of sodic sulphide, and that this compound will form when mercuric sulphide is present. The latter possibility is the more important one, but the former is manifestly one of interest to chemical geology.

A train of thermochemical reasoning, upon which it is not necessary to enter here, makes it extremely probable that, at temperatures exceeding 80°, a certain amount of sodic sulphide may form by the decomposition of neutral sodium carbonate and sodium sulphydrate in the presence of acid sodium carbonate. The behavior of such mixtures to mercuric sulphide at the temperature indicated is also such as it would be if the sodic sulphide actually formed; but a full and sufficient proof of the reaction which theory indicates as probable seems very difficult and has not yet been accomplished. It is certain, however, that a tendency exists to the formation of sodium sulphide under these conditions. When in addition to this tendency, the affinity of mercuric sulphide for sodic sulphide is brought into play, it can be proved experimentally that sodic sulphide is formed. We found that at a temperature of about 90° a mixture of the two carbonates and the sulphydrate dissolves mercuric sulphide freely without a sensible evolution of gas. If the solvent does not contain sodic sulphide, it must contain the sulphydrate. Hence it becomes important to ascertain the behavior of mercuric sulphide to sodic sulphydrate at moderately elevated temperatures.

While sodic sulphydrate will not dissolve a trace of mercuric sulphide at ordinary temperatures, if mercuric sulphide is added to a solution of sodium sulphydrate which stands upon the water-bath, hydrogen sulphide is evolved and mercuric sulphide goes into solution. The fact that hydrogen sulphide is evolved demonstrates that sodic sulphide must be formed. Cooling does not reprecipitate the mercuric sulphide, and the compound dissolved is therefore of the form HgS, nNa_2S. Though the solubility of mercuric sulphide in warm solutions

of the alkaline sulphydrates at ordinary pressures has, so far as I know, never been explicitly stated, I have no doubt that chemists have observed it and that, in consequence of this observation, the general statement of the solubility of mercuric sulphide in alkaline sulphydrates has remained in chemical literature in spite of the observation of Weber and Barfoed. The preparation in which I originally observed this important reaction was one from which mercury had already been removed by precipitation with hydrosulphuric acid. The experiment was afterwards repeated by Dr. Melville with several preparations of sulphydrate which had been accurately analyzed and had been tested in numerous ways. Now in a mixture of the carbonates and sulphides of sodium at the temperature of the water-bath, either sodic sulphide or sodic sulphydrate is present, or, more probably, both coexist. If, then, mercuric sulphide is added to such a solution, either sodic sulphide combines directly with mercuric sulphide, or sodic sulphydrate is decomposed by mercuric sulphide setting free hydrogen sulphide, which must be immediately absorbed by neutral sodic carbonate. Hence in any case the salt dissolved in the mixture must be of the form $HgS, n Na^2S$.

Effects of dilution—Laboratory experiments are usually made with solutions which are much more concentrated than those found in nature. Hence the effect of dilution on solutions of $HgS, n Na^2S$ are important. Whether mercuric sulphide is dissolved in a mixture of sodium monosulphide and sodium hydrate, or of the former and sulphydrate, dilution with cold water precipitates mercuric sulphide.

The cause of this precipitation, which is attended by some curious phenomena to be described hereafter, is clear. It is known through the investigations of Messrs. Kolbe, Thomsen and others, that while in moderately concentrated solutions

$$NaHS + NaHO = Na^2S + H^2O,$$

this reaction is partially reversed on dilution; or that, in the presence of much water, sodic sulphide is decomposed by water, the proportion of the sulphide undergoing this decomposition increasing gradually with the dilution. It is evident that the decomposition of $HgS, n Na_2S$ is effected in the same way, more and more of the monosulphide being converted into the sulphydrate as the dilution increases, probably without any limit. Since mercuric sulphide decomposes hot sodic sulphydrate, the effect of dilution in hot solvents will evidently be less than in cold ones.

Brunner* found that dilution of solutions of his salt precipitated a black mass in which, on examination with the

* Loc. cit.

lens, minute globules of mercury were visible. The quantity of mercury was extremely small, so that the precipitate on analysis corresponded very closely indeed to the composition expressed by the formula HgS. Gmelin-Kraut* appear to have some independent confirmatory evidence on this point. If metallic mercury is precipitated in diluted solutions, of course sulphur is liberated; and, as shown above, sodium hydrate must also be present. Now when these two substances are brought in contact, sodic hyposulphite forms. Accordingly Brunner found hyposulphite in the solution forty years before the decomposition of sodic sulphide in dilute solution had been elucidated.

As Brunner experimented with HgS, Na^2S, I thought it best to compare the action of HgS, $4Na^2S$. A very concentrated perfectly clear solution of freshly prepared mercuric sulphide in a mixture of sodic sulphydrate and caustic soda, containing very little of the latter, was suddenly diluted with cold water to 200 times its volume and rapidly filtered. Minute globules of mercury could be seen with the black sulphide on the filter. On digestion (after thorough washing) with very dilute nitric acid, a solution was obtained from which sulphydric acid precipitated black sulphide. The decomposition thus appears to be the same in each of the compounds, HgS, Na^2S and HgS, $4Na^2S$.

Influence of foreign substances.—The fact that sodium carbonates do not prevent the solution of HgS in Na^2S is evident both from Méhu's result and from our own. Experiments show that borax solutions precipitate a portion of the mercury from solution, but not the whole. The precipitation does not appear to be progressive, like that accompanying dilution, but to reach a sharp limit beyond which further additions produce no effect. A large amount of borax added to a concentrated solution of Na^2S and NaHS does not rob it of the power to dissolve HgS. It is easy to imagine reactions by which borax may precipitate a portion of the mercuric sulphide. But the behavior of solutions of borax to sulphydric acid and to alkaline sulphides is very peculiar and, so far as I am aware, has not been thoroughly investigated.† Very concentrated solutions of sodium chloride do not precipitate mercuric sulphide from strong solutions in mixtures of sodic sulphydrate, and they even appear to delay but not to prevent, precipitation by dilution

Solubility of Fe^2S.—The sulphide which is most frequently associated with that of mercury is pyrite or marcasite, indeed these minerals in greater or smaller quantities are to be found in nearly every hand specimen of ore, and occur very abundantly in most quicksilver mines. On making the experiment

* L. c., vol. iii, p. 851. † Gmelin-Kraut, l. c., vol. ii, p. 160.

I found that pyrite, marcasite or precipitated ferrous sulphide when warmed with a solution of sodic sulphide diminished in quantity, while the solution changed color. The filtrates gave strong reactions for iron.

Pyrite dissolves in cold solutions of sodium sulphide without any evolution of gas. The solvent power seems to increase with the temperature. Pyrite like cinnabar appears totally insoluble in cold sodium sulphydrate, and, like cinnabar, pyrite dissolves to some extent in hot solutions of the sulphydrate. Pyrite is also soluble in solutions of sodium carbonate partially saturated with sulphydric acid, both hot and cold. Quantitative determinations have been made, but are omitted here for the sake of brevity.

Marcasite is more easily soluble than pyrite, and the simple precipitated sulphide goes into solution most readily of all. I think there can be no doubt that pyrite and marcasite form double salts with sodium sulphide entirely analogous to the soluble compounds of mercuric sulphide. Marcasite is more easily attacked than pyrite, just as metacinnabarite is more susceptible to the action of reagents than cinnabar.

Solubility of gold.—The association of gold and pyrite is world wide. According to Gahn* there is no pyrite which does not yield traces of gold when carefully tested. This indeed does not accord with my experience, for extremely careful tests of some pyrite in my laboratory have failed to reveal any indication of gold. Gold is associated with quicksilver, however, at Steamboat Springs, at some points on the gold belt of California, at the Manzanita mine, at the Reddington mine, and some other localities both in California and in foreign countries. From these facts I concluded that gold should be soluble in sodic sulphide. On warming chemically pure, precipitated gold-dust with a solution of sodic sulphide, the glittering scales of gold gradually disappeared. The filtrate after proper manipulation yielded a purple precipitate with phosphorous acid.

A solution containing 843 parts of Na^2S (by weight) dissolves one part of gold at the ordinary temperature of the atmosphere. Gold also dissolves at ordinary temperatures in sodic sulphydrate, and in solutions of sodic carbonate partially saturated with sulphydric acid. The solubility appears to be increased and facilitated by heat.

Solubility of other sulphides.—Cupric sulphide dissolves less readily than pyrite in sodic sulphide and in mixtures of the sodic carbonates and sodic sulphydrate. Unlike pyrite, it also dissolves in thoroughly saturated sodic sulphydrate. Zinc sulphide is also soluble and behaves much as pyrite does. Quantitative determinations of the solubility of these substan-

* Bischof's Chem. Geol., vol. iii, p. 939.

ces have also been made. The solubility of the sulphides of arsenic and antimony in sodic sulphide and in the sulphydrate is of course well known. In the presence of neutral sodic carbonate sulphides of arsenic and antimony dissolve in sodic sulphydrate without the evolution of gas, because the sulphydric acid set free reacts upon the carbonate.

Natural solutions and precipitations.—The foregoing experiments show that there is a series of compounds of mercury of the form HgS, nNa^2S one or the other of which is soluble in aqueous solutions of caustic soda, sodic sulphydrate or sodic sulphide, and apparently also in pure water, at various temperatures. These solutions subsist, or subsist to some extent in the presence of sodic carbonates, borates and chlorides. There is the strongest evidence that the waters of Steamboat Springs contain mercury in this form, and that the waters of Sulphur Bank have contained mercury in the same form, if indeed they do not still carry it in solution. Bisulphide of iron, gold and zincblende form double sulphides with sodium, which appear to be analogous to those of mercury. Copper also forms a soluble double sulphide, but combines more readily with sodic sulphydrate than with the simple sulphide. All of these soluble sulphosalts may exist in the presence of sodic carbonates.

Mercuric sulphide is readily precipitated from these solutions. Any substance is more soluble in hot solutions than in cold ones, provided that increase of temperature does not resolve the fluid molecules into others which are less soluble; as happens with sodium chloride, neutral sodium carbonate, etc. Diminishing temperature is thus a cause of precipitation, and diminishing pressure appears to act in a similar way. There are also other methods of precipitation which may be carried out under natural conditions. If a natural solution of mercury comes in contact with strong solutions of borax, or with sulphydric acid, or any stronger acid, it will lose a portion of the mercuric sulphide in solution. At Steamboat Springs and Sulphur Bank large quantities of sulphuric acid are formed near the surface and, percolating downward, must precipitate mercury in some form. The acid waters penetrate to a depth of at least 20 or 30 feet and this explains the fact that the waters reaching the surface carry so little quicksilver. These same causes must also produce precipitation of the other ores and of gold from solutions.

Another method by which mercuric sulphide may be precipitated, as has been seen, is mere dilution. Now, ascending solutions of quicksilver must sometimes meet with springs; and when they do so, metacinnabarite, or black sulphide will be precipitated, and with it also a small amount of quicksilver. In nearly all mines a small quantity of "virgin" quicksilver

is found and in most it constitutes a very small proportion of the entire ore.* Accompanying this precipitation is the formation of hyposulphite, which actually occurs in the waters of Steamboat Springs. Dilution of solutions of quicksilver with extraneous spring waters thus explains the occurrence of metacinnabarite, found in at least four of the mines of California, and in New Zealand, and of native quicksilver. Native quicksilver however occurs in many mines in which no metacinnabarite has ever been seen. This does not preclude the supposition that the metal has been isolated by dilution; for black sulphides in the presence of solutions of mercury might readily be converted into the allotropic modification, and I know of no reason for denying that much of the cinnabar of the ore deposits may have been deposited in the amorphous state. Cinnabar and metacinnabarite are sometimes found mixed, as if the conversion to the red form were incomplete; and there is other evidence from observation that mercuric sulphide is slightly soluble in the waters of some of the cold mines.

While dilution will produce metallic mercury and a *causa vera* of its existence is thus detected, there may be other ways besides this in which it is produced in nature. Thus sulphydric acid precipitates a mixture of quicksilver and mercuric sulphide from mercurous salts. Whether soluble mercurous salts can occur in nature, excepting near the earth's surface, is another question. But even light is well known to decompose this feeble sulphide, and it is not impossible that the decomposition of organic matter, which is associated in most cases with cinnabar deposits, and seems to be specially abundant in the mines in which metallic mercury most prevails, may yield ammonium sulphide and metallic mercury.

Conclusions.—The conditions of the solution and precipitation of ores traced in this paper appear beyond doubt those mainly instrumental in forming the deposits of Steamboat Springs and Sulphur Bank. Most of the other quicksilver mines in California show ores and gangue minerals of similar composition to these, and many of them are accompanied more or less closely by warm springs containing much the same salts in solution. Some of the gold veins also appear to bear so considerable a resemblance in many particulars to these deposits as to lead to the belief that they too were formed by precipitation from solutions of soluble double sulphides.

That pyrite, gold and other ores are sometimes produced in nature by other methods is absolutely certain; for some auriferous pyrite is known to have resulted from the reduction

* It is a very curious fact that from ancient times to the beginning of the last century virgin quicksilver was supposed to possess qualities superior to that of the metal reduced from cinnabar. Brückmann, Magn. dei in loc. subt.

of iron sulphate by organic matter. This particular process is probably confined to short distances from the surface; for I know of no indication of the formation of iron sulphate far from the oxidizing influence of the atmosphere. But there may be other solvents yet for these and other minerals which can form at great depths and, if such there be, I am convinced they are cases in which they, and not those which it has been my good fortune to trace in the foregoing pages, have been instrumental in the segregation of ores.

U. S. Geological Survey, Dec., 1886.

Art. XXIV.—*Fluviatile Swamps of New England;* by N. S. Shaler.

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In examining the fresh water swamps of New England I have found it necessary to consider in a careful manner the geographical distribution of one class of these deposits, viz: The swamps formed along the banks of rivers. This work has been done with the intention of presenting the matter in a report on the inundated lands of the United States, but a part of the results seem to have an important bearing on the question of recent changes in the altitude of the continent in relation to the sea and are therefore stated in the following pages in order that they may be at the service of students who are interested in this problem.

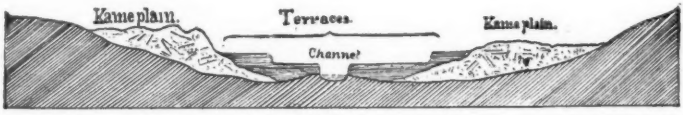
Let us first note the fact that the greater part of the New England streams flow from north to south or with slight deviations from this direction. Except at the head-waters of these southward flowing streams, where the brooks have too little volume to clear their beds of the glacial waste which encumbers them, the valleys of this group contain no swamps. There are, it is true, occasional small areas of marshy ground upon the bordering terraces of these rivers; these, in all the cases I have examined, are evidently "moats" or the cut-off portions of the old stream beds which have been abandoned by the rivers in their changes of channel.

All these southward flowing streams show that they have, for a considerable time, been cutting their beds downward through a deep layer of detrital material which was evidently deposited in their channels while the ice sheet was disappearing from the district on which they lie. This is indicated by the fact that, above the alluvial plain, at present overflowed in the times o flood, there is usually one, occasionally several, terraces which bear the mark of river action and to which the stream never attains.

It is a fact, one that so far as I am aware has not been noticed, that the uppermost of these terraces in the Merrimac and Connecticut, as well as some other rivers, generally exhibits features not reconcilable with the supposition that it was formed by river action. Its surface is frequently cast into the peculiar forms characteristic of the deposits which were made at the front of the ice-sheet when the base of the glacier lay below the level of the sea. It is my belief that these kame-bearing terraces were formed while the valleys in which they lie were depressed. Mr. Warren Upham in his essay on the New Hampshire drift, repeatedly refers to the fact that these plains differ essentially from those forming at present, still he conceives them as formed by river action.

Although we must exclude the upper terraces, those having kame ridges and the crater-like hollows which accompany kame deposits, from the category of terraces formed by the action of rivers, there remain enough of the elevated benches, distinctly marked by the action of fluviatile forces, to make it clear that, in the valleys of the rivers flowing from north to south, the conditions have been such that the streams have had no difficulty in constantly cutting deeper and deeper into the detrital deposits which hindered their flow at the close of the Glacial period. The accompanying diagram (figure 1) represents the general condition of the terraces in the valleys of the Merrimac, Connecticut, and other New England rivers of considerable size, which flow from north to south. It is intended to give the typical form of these terraces and not to show the actual conditions at any one point, though those who are familiar with the aspect of the Merrimac or the Connecticut will recall many sections which it closely resembles.

1.



Type of river valleys in New England when the streams flow from north to south.

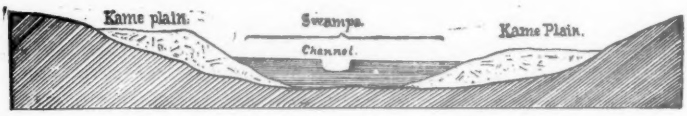
It is evident that in a valley characterized by the presence of the terrace debris the conditions are extremely unfavorable for the formation of swamps, for even the lowest of the alluvial plains is drained, except in times of flood.

Turning now to the streams which flow from south to north we find conditions in marked contrast to those which are found in the rivers flowing in the opposite direction. The number of these northward flowing streams is small and none of them have drainage areas to be compared with those of the greater

New England rivers. So far I have been able to examine the valleys of but few of this group, viz: The Nashua, the Concord, the Charles, and the Neponset, all situated in eastern Massachusetts. Although these streams are not large they all carry, in times of flood, large bodies of water.

The general conditions of their drainage basins, as far as can be shown by a cross section, are exhibited in diagram No. 2. It will be seen from a comparison of this with the preceding diagram (figure 1) that the most important difference in the cross section is as follows, viz: Along the streams which flow from south to north there are no river terraces except those which are covered by the ordinary floods and are at times swampy; while in the rivers which flow in the opposite direction there are normally several of these elevated fluviatile benches and even the lowest of them is well drained in the dry season. The only benches are of the kame terrace character before adverted to and these are very conspicuous features in some of these valleys; in that of the Concord River they are particularly extensive and characteristic. At first sight these kame plains are likely to deceive the unwary observer into the belief that he has ordinary fluviatile terraces before him. Even when he has a considerable acquaintance with such terraces as abound in the region south of the glaciated area of this continent he may fall into this error. Seen from the level of the streams the faces of the kame terraces where they have been scarfed away by the stream are almost exactly like those of ordinary fluviatile benches. Observing them closely their escarpments are seen to be slightly more irregular than on the terraces formed by a stream in its down cutting, but occurring, as they do, in a somewhat fragmentary way, these peculiarities are readily overlooked.

2.



Type of river valleys in New England when the streams flow from south to north.

When, however, the student ascends upon the surface of these plains, he at once remarks that they are essentially unlike the true fluviatile terraces as we may call those benches which have in earlier times been overflowed by the stream. In place of the level or slightly rolling surface characteristic of these old flood plains we find these kame terraces, though generally nearly level, to be here and there deeply indented by the peculiar pits termed 'kettles' so characteristic of the kame

plains of New England. Here and there also we find low but sharp kame ridges which are equally characteristic of this class of deposits. These contours are of themselves sufficient to prove that these areas have never been the flood plains of any river. . Other evidence is found in the fact that these kame bearings terraces have bowlders scattered over them; usually these erratics are of small size, but occasionally they have a mass of twenty cubic feet or more. The materials which form the kame plains consist in the main of sand and pebbles deposited in an irregular, cross-bedded way quite different from the structure of fluviatile terraces. Again the kame plains may be traced completely beyond the valleys into positions where it is evident that they have no relation to river action.

Below the level of this kame terrace the valleys of the rivers which flow from south to north show no other benches until we descend to the level of the present flood plain. This is always, as is shown in the diagram, in direct communication with the present margin of the river so that a very slight flood sends the water over the whole of its level. Even in the times of ordinary low water the river extends through sedgy flats for some distance from the margin of the flowing stream. The whole of this alluvial plain is swampy; so far as I have seen none of it is exempt from floods, and there is, at no point, any indication of down-cutting on the part of the stream bed. This absence of a distinct lowering of the drainage level in these basins may possibly be accounted for in part by the fact that they are all more or less obstructed by mill-dams. Still making all allowance for these obstructions and considering only the conditions which remain when the water is drawn away from the pools, it is clear that there has been in these channels an entire absence of that swift down-cutting which is so marked a feature in the rivers which flow from north to south.

It is moreover clear that the reverse process is now rapidly in action; none of these northward flowing streams have, at the present time, sufficient currents to clear their beds of the detritus brought into them by floods from their tributaries. Even in the time of floods they discharge no coarse detrital matter; only the small amount which is held in suspension by a slight current is carried to the sea. The result of this failure of the streams to exercise any general erosive effect is that the process of deposition is constantly going on not only on the bottoms of their channels but upon a wide field on either side of the waterways. The deposition of coarse sediment is taking place not only along the bottoms of the streams but in the form of small deltas where the brooks from the higher ground are arrested in their speed at the margins of the swamp lands. These deltas are inconspicuous; in part because the greater number of the

New England streams do not bear a large amount of coarse sediment, but also because the continued rise of the swamp deposits causes the deltas to be masked by the growth of plants and the accumulation of peaty matter. It seems evident that we have not yet come to a point where the conditions have attained their equilibrium though it may well be that the present condition of these basins is affected by the artificial dams which have recently been constructed across their main channels. I believe that, if these dams were removed, the accumulation of detritus would continue.

The general character of the swamps which border the northward flowing rivers, merits some consideration. In the first place we note the fact that they do not belong to the group of sphagnum deposits, for the reason that the alternations of water level are too great to permit the extensive development of these mosses. These fluviatile swamps are divisible into three classes. There are those which are formed in areas so frequently subjected to overflow and so constantly penetrated with water that they cannot afford a site for any of our perennial shrubs to maintain a place upon them. These areas are occupied in their lower part by rushes and in the higher by the ordinary marsh grasses of this country. Above this level we have a belt or ground, generally narrow, in which the grasses give place to various bushy but low growing plants of which the alders are the most common. Above this we have in certain places a wide field of swamps which are really only very wet woods, water covered in the times of the greater floods, say once or twice a year, but generally two or three feet above the level of ordinary inundations.

These wide inundated plains demand explanation; this I am not yet able to give. It seems to me, however, from their aspects and the trifling sections I have been able to secure, none of which extend more than three feet below the surface, that they may be true terrace plains formed perhaps during a time when the channel of the river was at a lower level than it is at present. These plains may have been converted into swamps by the same changes in the drainage conditions which have so embarrassed the flow of the stream.

The foregoing statement will make it clear that there is a great difference in the drainage conditions of the streams which flow from and toward the north in the belt of country included in eastern New England. A little further consideration of the facts will make it also clear that this difference is probably not one of the original nature but has recently been brought about. We note in the first place that the valleys of the rivers, which flow from south to north, show evidences of an erosive power which the rivers no longer possess. As is indicated in the dia-

gram (see figure 2) we often find on either side of the present stream bed the remains of a terrace-like mass of sand and gravel which is the product of peculiar conditions of the Glacial period. In some rare cases these masses of tabular drift are found as fragments of an old table-land left in the middle of the valley. These lateral and central masses of terraced sands have in all cases steep escarpments which by their slope indicate the erosive action of the stream. It is often evident that these drift plains at the close of the Glacial period extended across the valleys in which they lie.

In some cases the mass excavated is very great; on the average it seems to me as great as that which has been removed by some of the larger streams of the valleys which flow from north to south. The excavation in the valleys of the rivers which flow from south to north is entirely beyond the power of their streams to accomplish with their present slopes. In similar streams flowing in the reverse direction the process of erosion of their drift plains is still going on. In the Merrimac, for instance, the river is rapidly wearing away its banks at many points. On the western side of the elevated plateau of kame plains, which lies on the east side of the river near Concord, N. H., the process of erosion keeps a fresh face on a cliff nearly one hundred feet high and several hundred yards in length. This escarpment is wearing away at the rate of somewhere near one foot per annum. The same is the case with many other bluffs on this stream. This activity of erosion by the rivers is seen in many other streams of this class in this part of New England, but in the valleys which slope to the south the streams no longer attack their banks in this manner though it is evident that they at one time were capable of such work.

I have at present no data sufficient to determine the depth to which the valleys have been encumbered by the swamp accumulations which have been formed in them or how much their beds have been raised from their original level. It seems to me likely that they originally possessed alluvial plains such as those which now characterize the Merrimac and other normal valleys. This would seem almost necessarily the case from the extensive erosion of the drift terraces, for the reason that this erosion by the stream would necessarily lead to the oscillation of the channel from side to side, which would bring about the production of fluviatile plains. If such plains existed the filling up of the valleys has evidently been sufficiently great to suppose their surface beneath the existing swamp deposits. As before remarked I am disposed to believe that the great area of wet-woods on the banks of the Concord river in Bedford, Mass., is in its nature a supposed fluviatile terrace.

It thus appears probable that after the streams which flow to

the northward had in good part done their work of excavating their drift-encumbered channels, bringing them into essentially the condition of those occupied by the rivers flowing from north to south, a change came over them which led to a lowering of their slopes and a consequent diminution of their fall. It is evident that the only change which could produce this would arise from a tilting of the land area in which they lie. This tilting might be accomplished by a positive down sinking of their head waters or by a positive elevation of the lands about their mouths; either of these movements might be local in their nature or they might be a part of a general movement of the continent.

It is perhaps too soon to interpret the movements which have led to these peculiarities in the drainage of the two classes of our New England rivers, but in order to secure a basis for the further study of the facts I venture to give the succession of events which my observations appear to indicate.

First as to the origin of the kame terraces which are by far the most conspicuous as well as the most inexplicable features of our river valleys. I have already incidentally given the principal reasons why they are not to be considered as in any way the result of river action. I have stated that the character of their surfaces as well as the order of stratification of their materials excludes them from the class of fluviatile deposits. A further study of their features shows us that there are other reasons why they cannot be regarded as the product of river action. Deposits of essentially similar nature are found along the shore line at many points between Portland and New York, especially on Cape Cod and the islands of Nantucket and Martha's Vineyard where the supposition of river action is quite out of the question. Again they are found in the valleys of our smaller lakes in positions where they could never have been exposed to river currents. Still further they are, when found in the river valleys, in no very definite relation to the plane of the stream, they lie at all heights above its level and only for short distances and accidentally correspond in slope with the surface of true fluviatile plains. I am, therefore, driven to the opinion that these kame terraces were formed beneath the level of the sea during the submergence which attended and followed the stage of the Glacial period when this surface was deeply covered with ice. During the period of submergence which endured for a time after the disappearance of the ice the surface of the sea floor was swept by strong currents which tended to move the detrital matter from the elevations and accumulate it in the hollows of the bottom. The currents which bore the materials to the sea and arranged them on its floor were in the main produced by the sub-glacial streams

which emerged from beneath the ice while its base lay in the sea. As the sub-glacial streams normally had their points of discharge at the lowest parts of the ice front, the greater part of the kame gravels were deposited in the depressions of the sea floor which have since become river valleys. But a share of this debris found its way to the higher lying districts and occasionally occupied positions on the divides between adjacent valleys.*

When the surface of this district rose above the level of the sea the movement took place suddenly as is shown by the preservation of the delicate features of the kames, especially along the sea shore as well as by the absence of old benches of levels above the plane of the present shore. The elevation probably brought the level of the land to a position considerably above its present altitude, as is shown by the submerged forests along the shore of Massachusetts Bay and on Nantucket, where there has been a down sinking of ten to twenty feet in depth since the post-glacial elevation.

During this period of post-glacial elevation, when this part of the continent was somewhat higher than at present, the valleys of all the streams were, to a greater or less extent, cleared of their incumbrance of drift. It is during this period that the valleys of the rivers which flow from south to north were exposed to the measure of erosion which we find indicated in them. This condition of the surface must have endured for some thousands of years in order to have permitted the removal of such extensive masses of debris as have been cleared from these valleys. As before remarked, the erosion of these valleys as far as it is measured by the abrasion of the original drift deposits, the kame terraces and other glacial materials, is nearly if not quite as extensive in the valleys whose streams flow to the northward as in those that decline to the south. It is evident that the elevated condition of the continent endured long enough to permit the complete re-establishment of the drainage in the drift-encumbered valleys of this region, a process which could not have taken place with the present declivity of the streams. When the change in the position of the land came about it led to the relative lowering of the southern part of New England and a corresponding relative increase in the height of the northern part of this section of the shore. It is not perfectly clear whether the movement actually lifted the northern districts above their previous level or no, but it seems likely there was a positive sinking of the southern section.

It is probable that the submerged forests and swamps of southern New England before and after, referred to, were depressed beneath the sea level at the time of this movement.

* Compare on the Origin of Kames, by N. S. Shaler, Proceedings Boston Soc. Nat. Hist., vol. xxiii, pp. 30–44.

The amount of downward movement indicated by these remains of submerged land plants cannot well be less than fifteen feet. It may have much exceeded this amount. It is impossible to determine by the scanty remains of these submerged forests and swamps, which are disclosed along the shore line, just how high above the water the surface which they occupy stood before they were lowered beneath the sea. Therefore, although a certain amount of subsidence of the region appears to be indicated by these submerged plants, the amount of the movement can only be determined by a careful examination of the valleys themselves. Fortunately the data obtainable in this manner seem to make an approximate determination of the point in question. The evidences of former erosion which these valleys afford shows us that at one time their rivers had a rate of flow comparable in a general way to that of the rivers which flow from north to south. The question is, how great a tilting of these basins would be required in order to bring the streams to their present condition of relative stagnation and permit the development of the swamps which now characterize their basins. After the careful study of these valleys, comparing them with those in other districts, I am of the opinion that the tilting need not have exceeded two feet to the mile to have effected the change, and that it might have been effected with a somewhat less amount of alteration in the inclination of the stream beds. The least amount which would satisfy the conditions would be a lowering of the inclination of the river beds by one foot to the mile. The greatest submergence which I have been able to prove from the evidence of buried forests is in the region about Boston harbor, where it appears to have been somewhere about twenty feet, rather less than more. This evidence is derived from some roots of a species of spruce obtained in Cambridgeport at a depth of about seventeen feet below high water, and some traces of roots of trees in their natural position below the level of low tide mark in the portion of Massachusetts Bay near Lynn. Now, from the sources of the Concord river to its outlet into the Merrimac, is a distance of about thirty miles in a direct line, and by the sinuosities of the stream is about forty miles. We see, therefore, that the proved subsidence, since the close of the Glacial period, is hardly sufficient to account for the change in the condition of the river, though it represents at least half the amount necessary to bring about that alteration.

The moderate amount of the subsidence which has led to the swampy condition of these valleys is furthermore indicated by the fact that when the tributaries of the embarrassed streams, themselves flowing from south to north, are so placed that their original descents were steep, they have not had their basins made swampy by the change of inclination.

It is clear that the precise amount of this dislocation cannot be determined from a study of the streams themselves; we can only set it in general terms as equivalent to a diminution in the rate of descent to the amount of from one to two feet to the mile. It is, however, clear from the evidence afforded by the valleys that the change was in effect a downward tilting of their southern ends. This is shown by the fact that the encumbering by marshes often extends to the head-waters of the streams. If the subsidence had consisted in an even lowering of the whole shore the result would have been the checking of the current of the rivers in the lower part of their course alone. As it is, it has affected the movement of some of their tributary streams up to a height of one hundred feet above the sea. There is a chance that the amount of the dislocation may be determined in the manner pursued by Gilbert in his admirable work on the lake basins of the central and western portions of the continent, viz: by tracing the elevated shore lines of shrunken fresh water areas. In the essays which I have made towards the use of this method I have as yet attained no success, for the reason that over New England elevated shore-lines are rare and extremely indistinct in their outlines. It is likely, however, that a careful study of the numerous lakes of New England which have been partially drained since the Glacial period will afford some data for the accurate determination of this question.

An inspection of the best accessible maps seems to show that this encumbering of the valleys of the streams which flow from south to north, becomes less evident as we recede from the shore. It is but slightly shown in the hill districts of southern New Hampshire, or of central Massachusetts, as well as in the Berkshire hills. It will not do, however, to conclude that this tilting action did not take place in those districts. The only streams which in that region have a course from south to north are of small size, and rapidly descend from considerable heights. If, as seems likely, the amount of down sinking of the level to the south did not exceed two or three feet to the mile, the original slope of the stream beds may not have been so far overcome as to lead to the formation of swamps in their valleys.

It need hardly be said that this tilting movement was most likely a change which involved a large part, if not the whole, of the glaciated district of the continent. The occurrence of such a movement is sufficiently proved by the position of the post-glacial beds containing marine fossils along the shore from northern New England to Greenland, as well as by the evidence obtained by Gilbert from the old shores of Lake Ontario. These observations above recounted on the northward-flowing

streams come, therefore, as a corroboration of an hypothesis which has perhaps sufficient verification from other evidence. The chief interest of the facts indicated by the valleys we have been discussing is that they give an approximate measure of the amount of dislocation of the continent on the southern part of New England, and that they apparently show that the down-tilting took place in relatively recent times, and after a period of elevation during which the streams had steeper slopes than they at present exhibit.

I venture to suggest that the uplifting probably took place during the period of retreat of the New England glacial sheet, and before the ice had passed away from the northern part of the continent, and that the down tilting occurred when the ice had been in good part, if not completely, removed from the northern regions. It seems to me not improbable that the upward movement which followed the retreat of the ice was due to the removal of its weight from the surface of the continental arch. Assuming this to have been the case then we can easily imagine that in the region which was at a certain distance to the south of the retreating glacial escarpment would be temporarily elevated by the counter thrust arising from the weight of the neighboring ice. We may aid ourselves in forming this conception by the somewhat similar case in which the surface of a peat bog rises above its original level around the part which is weighted down by the filling of a roadway. It is easy to see that if we should remove the weight which produces the counter-thrust the elevated surface would tend to resume its original level.

We may thus conceive the succession of movements which have led to the present condition of our streams flowing from north to south, as follows, viz: 1st. The subsidence of the land surface under the weight of the ice to a depth below the level of the sea. 2d. With the retreat of the ice, a reëlevation, in a sudden manner, to a height much above the level of the sea. 3d. With the disappearance of the ice from the continent a readjustment of its position and a consequent lowering of the southern portion of the glaciated area. It is not likely that in the readjusted condition of the continent all parts are equally elevated or equally lowered. The present levels of the several divisions of the continental area would probably be determined by complicated equations of thrusts, and it is probable that in this way we may explain the fact that certain of the lesser valleys of New England show little effect from the tilting movement which in immediately contiguous areas has had a great influence in the flow of the streams. I have observed the fact that in the hills of Mt. Desert we have evidence which goes to show a rising of the shorelands from the sea by a succession

of uplifts, each separated from the others by a period in which the land remained in the same relative position to the sea for a period of time sufficiently long to permit the waves to excavate a strongly marked bench while in the intermediate sections the elevation took place so rapidly that the drift coating was not swept away from the rocks. It seems at present likely that these benches on Mt. Desert do not correspond with any similar coast lines in the southern part of New England. If this is proved to be the case then we have evidence that the rate and manner of upward movement were very diverse in regions which are close together.

Although in this paper I propose to limit the matter of inquiry in the main to the post-glacial changes which have come upon the valleys of the northward-flowing streams it may be noticed that the facts above referred to throw much light upon the preglacial attitude of the continent. These river-valleys retain the general form which they had before the last glacial ice began to act upon them, they pursue their present courses because their flow is mainly determined by the existence of the pre-glacial river valleys in which they lie. It is clear that these valleys could not have been excavated by streams of their present slope, it seems, therefore, necessary to assume that the descent of the northward flowing rivers must have been more rapid in the pre-glacial times than it is at present, or, in other words, this part of the continent was at that time relatively less elevated in its northern parts than it is at present.

Art. XXV.—*On the Mazapil Meteoric-iron, which fell November 27th, 1885;** by William Earl Hidden.

Among the large number of meteoric irons which have been described, only eight† are recorded as having been seen to fall. It is my privilege to be able to add a ninth fall to this short list, and one which may prove to be of exceptional scientific importance. This mass of meteoric iron I received in August last as a gift from my friend, Professor José A. y Bonilla, Director of the Astronomical Observatory at Zacatecas, Mexico. He stated that it was *seen to fall* at about 9 P. M. on the 27th of November, 1885, during the periodical star-shower of the "Bielids." Such is the great interest of this meteorite,

* This meteorite was first announced on Jan. 17, 1887, before the New York Academy of Sciences, at a regular meeting.

† Agram, Croatia, May 26, 1751: Charlotte, Dickson Co., Tenn., Aug. 1, 1835; Braunau, Bohemia, July 14, 1847; Tabarz, Saxony, Oct. 18, 1854; Victoria-West, Africa, in 1862; Nejed, Arabia, spring of 1865; Nedagolla, India, Jan. 23, 1870; Rowton, Shropshire, England, April 20, 1876. See the catalogue of the meteorites in the Mineral Department of the British Museum, by L. Fletcher, p. 42.

as shown by its history, that I have delayed announcing it until the evidence of its fall had been substantiated as thoroughly as possible.

The general freshness of surface, which shows very perfectly the flow of the melted crust; the presence of unusually large nodules of a very compact graphite; the very slight superficial oxidation, and its dissimilarity to other meteorites of the region, are all interesting features of this iron, and serve to confirm the statement of its recent fall. When received it weighed about 3950 grams. Its present weight is 3864 grams, or ten pounds four and one-quarter ounces, troy. Its greatest length is 175 millimeters, as measured diagonally across the mass. In its thickest part it measures about 60 millimeters. It could be described as a flat irregular mass, covered with deep depressions, having a smooth surface. (See figure 1.)

The evidence of the fall is set forth in the following communication from Professor Bonilla.

(Translation).—"It is with great pleasure that I send to you the Uranolite which fell near Mazapil, during the night of the 27th of November, 1885. That you may the better appreciate the great scientific interest which this uranolite possesses, I will state that everything points to the belief that it belongs to a fragment of the comet of Biela-Gambart, lost since 1852. I here give you the history of this celestial wanderer. On the second day of December (1885) I received, to my great delight, from Eulogio Mijares, who lives on the Conception Ranch, 13 kilometers to the east of the town of Mazapil, a uranolite, which he saw fall from the heavens, at nine o'clock on the evening of the 27th of Nov., 1885. The fall, simply related, he tells as follows, in his own words :—

"'It was about nine in the evening when I went to the corral to feed certain horses, when suddenly I heard a loud sizzing noise, exactly as though something red-hot was being plunged into cold water, and almost instantly there followed a somewhat loud thud. At once the corral was covered with a phosphorescent light and suspended in the air were small luminous sparks as though from a rocket. I had not recovered from my surprise when I saw this luminous air disappear and there remained on the ground only such a light as is made when a match is rubbed. A number of people from the neighboring houses came running toward me and they assisted me to quiet the horses which had become very much excited. We all asked each other what could be the matter, and we were afraid to walk in the corral for fear of getting burned. When, in a few moments, we had recovered from our surprise, we saw the phosphorescent light disappear, little by little, and when we had brought lights to look for the cause, we found a hole in the ground and in it *a ball of light.** We retired to a distance, fearing it would explode and harm us.

* *Una bola de lumbre.*"

Looking up to the sky we saw from time to time exhalations or stars, which soon went out, but without noise. We returned after a little and found in the hole a hot stone, which we could barely handle, which on the next day looked like a piece of iron; all night it rained stars but we saw none fall to the ground as they seemed to be extinguished while still very high up.'

"The above is the simple recital of the ranchman, and the uranolite which fell is the one I send to you. From the numerous questions I have asked Sr. Mijares, I am convinced that there was no explosion or breaking up on falling. Others who saw the phosphorescence, etc., were Luz Sifuentes, Pascual Saenz, Miguel Martinez, Justo Lopez and some whose names I have not obtained.

Map of Mazapil, Mexico, and vicinity.

"Upon visiting the place of the fall (see accompanying map of the northern section of Mazapil in the State of Zacatecas) I was particular to examine the earth in and around the hole, and by careful search and washing the earth I found a few small bits of iron, which must have become detached from the uranolite when it penetrated the earth.

"The hole was thirty centimeters deep. Probably the light which was seen came from the volatilization of the surface of the celestial body due to the high temperature acquired by friction with the atmosphere, and of this volatilized matter falling to the earth as an incandescent powder."

The above communication was followed by an account* of

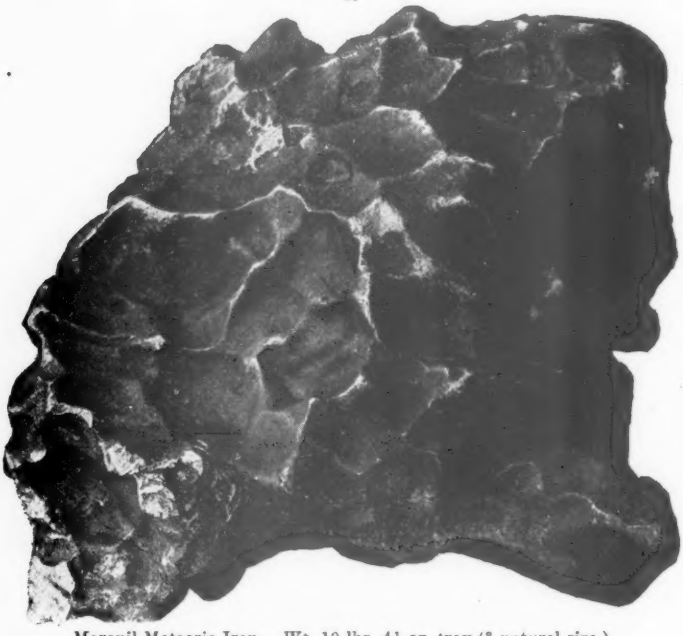
* For full text of which, see Annals of N. Y. Acad. Sci., for 1887 (now in press).

the observation of the Biela meteors at Zacatecas by Professor Bonilla and his assistants.

The locality of the fall is situated in latitude 24° 35′ North and in longitude 101° 56′ 45″ West of Greenwich.

That no explosion was heard when this iron fell, is paralleled by the account of the fall of the fifty-six pound aerolite near Wold Cottage, Yorkshire, England, on Dec. 13th, 1795. "This stone fell within ten yards of where a laborer was at work. No thunder, lightning, or luminous meteor accompanied the fall; but in two of the adjacent villages, the sounds were so distinct of something passing through the air towards Wold Cottage that several people went to see if anything extraordinary had happened to the house or the grounds." (L. Fletcher, An Introduction to the study of Meteorites, 1886, p. 22). Concerning the aerolites which fell at 11.50 A. M., on June 28,

1.



Mazapil Meteoric Iron. Wt. 10 lbs. 4¼ oz. troy (¼ natural size.)

1876, at Ställdalen, in Sweden, "it is remarkable that no meteor was visible at the place where the stones fell, though it was seen over nearly all Sweden."

The surface of the Mazapil iron is of great interest. The deeply hollowed depressions entirely cover the mass (see figure 1). A thin black crust coats the surface, and exhibits well

the striæ of flow, as seen on meteorites whose fall has been observed. In eleven places nodules of graphite are noticed extruding from the surface (the engraving shows some of these), one of them is nearly an inch in diameter. The graphite is very hard and apparently amorphous; troilite and schreibersite were noticed on a section cut off for analysis and for the development of the figures of Widmanstätten. The crystalline structure (fig. 2) is well shown in the engraving (Ives' process) which is of natural size. The lines are somewhat similar to those of the Rowton iron, in their width and distribution, and are very unlike the known Mexican irons from Toluca, Durango, Coahuila, etc.

2.

Section of Mazapil Meteoric Iron (natural size.)

In its surface and general flatness, the mass bears a remarkable resemblance to the Hraschina, Agram iron* which fell May 26th, 1751. In its weight it is nearly like the Irons of Rowton (7¾ lbs.), Charlotte (9½ lbs.), Victoria-west (6 lbs. 6 oz.), and Nedagolla (9¾ lbs.), which were all seen to fall.

Mr. J. B. Mackintosh has kindly analyzed a small fragment with the following results, which, for comparison with other irons, seen to fall, I have placed in tabular form :—

	Mazapil. Mackintosh.	Rowton. Flight.	Charlotte. Smith.	Estherville.† Smith.
Iron	91·26	91·25	91·15	92·00
Nickel	7·845	8·582	8·05	7·10
Cobalt	0·653	0·371	0·72	0·69
Phosphorus	0·30	----	0·06	0·112
	100·058	100·203	99·98	99·902

Carbon is distributed all through the iron between the crystalline plates, and it is noteworthy that this element was observed with the spectroscope as present in the "Bielids" of Nov. 27th, 1885. Chlorine is also present and shows itself by a slight superficial deliquescence. Of this latter I will state that most of the surface oxidation of the ferrous chloride has occurred since August last. As yet no tests have been made to ascertain the amount of occluded gases, or to analyze the graphite nodules, and it is probable that such analyses give only results

* See Beyträge zur Geschichte und Kenntniss meteorischer Stein- und Metallmassen, by Dr. Carl von Schreibers, Wien, 1820, plate VIII.

† Fell May 10, 1879 and contains embedded nodules of nickeliferous iron surrounded by silicates.

similar to those already obtained. Over the mass, where the crust has been accidentally removed, the lines of crystallization (Widmanstätten figures) can readily be traced without etching the surface. The abrasion due to impact was very slight.

In conclusion, we cannot, from the very circumstantial account of the fall, which in several paticulars contains heretofore unrecorded observances, and the corroborative evidence of the iron itself, decline to receive this meteorite as the ninth recorded fall of an iron mass to the earth; and perhaps at another period of the November "Bielids," this fall will be confirmed in all its interesting details. The interest connected with this meteorite, because of its beautifully marked and fresh surface, is enhanced by the concurrence of the time of its fall with the shower of the Biela meteors.

I wish to express here my deep obligation to Professor Bonilla for the interesting data concerning this meteorite, and for the gift of the meteorite itself, and to Mr. Mackintosh also, for his kind interest in making the chemical analysis.

ART. XXVI.—*On Observations of the Eclipse of* 1887, *Aug.* 18, *in connection with the Electric Telegraph;* by Professor DAVID P. TODD, M.A., Director Amherst College Observatory.

IN the proceedings of the American Academy of Arts and Sciences for 1881, at page 359, I suggested the use of the electric telegraph during total solar eclipses, and showed the applicability of the proposed scheme of observation to the eclipse of 1882, May 16. Had this suggestion been adopted, it is easy to see how the unique discovery of a comet by the Egyptian observers might have been verified, and important data obtained regarding the orbit of an object now lost. Interesting as such data would have been, however, they have slender importance in comparison with the results in solar research possibly attainable through the adoption of the proposed method of telegraphic transmission of important observations eastward along the path of central eclipse. In the same paper, I alluded to the eclipse of the coming summer as affording the most auspicious opportunity of the present century for the application of the telegraphic method, and it may be hoped that an attempt will be made toward getting something out of the suggestion on this occasion, as I learn, in a late letter from Dr. S. von Glasenapp, Professor of Astronomy in the Imperial University of St. Petersburg, that the Russian telegraph service may be expected to give the use of its lines at this time for astronomical purposes. Accompanying his letter, Dr. Glasenapp sends also the subjoined list of possible observing stations where telegraphic

communication is at hand. By plotting these upon a map, anyone may see the remarkably close coincidence of the path of totality with the extended lines of the Russian overland telegraph.

List of towns and places with Telegraphic Stations (longitudes from Greenwich) where the central eclipse of Aug. 18, 1887, may be seen.

(The places marked with an asterisk * lie very near the central line.)

Place.	N. lat.	E. long.
1. Velikije Louki	56°21′	30°30′
2. Toropetz,	56 29	30 38
*3. Beloi,	55 53	30 55
4. Sytchefka,	55 50	34 17
*5. Rjew.	56 16	34 20
*6. Zoubzoff,	56 10	34 35
*7. Stariza,	56 31	34 56
8. Kjatsk,	55 33	35 0
9. Torjok,†	57 2	34 57
10. Twer,	56 22	35 55
11. Volokolamsk,	56 2	35 57
12. Mojaisk,	55 31	36 11
13. Rousa,	54 42	36 12
14. Klinn,	56 20	36 44
15. Kortcheva,	56 47	36 51
16. Dmitroff,	56 21	37 31
17. Kashinn,	57 22	37 37
18. Kaliasinn,	57 15	37 53
19. Alexandroff,	56 24	38 44
*20. Pereiaslawl-Salesky,	56 43	38 49
21. Kirjatch,	56 10	38 52
*22. Petrowsk,	57 1	39 16
23. Rostoff,	57 11	39 25
24. Turieff-Podolsky,	56 21	39 41
25. Taroslawl,	57 37	39 54
26. Gawrilowsky Possad,	56 30	40 41
27. Souzdal,	56 25	40 27
28. Piszowo,	57 11	40 30
29. Nerehta,	57 28	40 34
30. Lejneff,	56 44	41 18
31. Kostroma,	57 46	40 56
*32. Tsanoff-Vosnesensk,	56 50	41 24
33. Kowroff,	56 23	41 18
34. Shouia,	56 51	41 23
35. Pless,	57 27	41 33
36. Soudislaff,	57 53	41 42
*37. Kineshma,‡	57 28	42 10
*38. Turiewetz-Podolsky,	57 19	43 8
39. Poutcheg,	56 59	43 11
40. Katounki,	56 50	43 15
41. Gorodez,	56 39	43 29
42. Makarieff na Oungé,	57 53	43 49
43. Semenoff,	56 47	44 29
44. Baki,	57 10	45 0
*45. Varnawinn,	57 23	45 3
46. Voskresenskoe,	56°53′	45°22′
*47. Vetlouga,	57 51	45 48
48. Taransk,	57 18	47 53
49. Kotelnitch,	58 18	48 22
50. Orloff,	58 32	48 55
51. Viatka	58 36	49 41
52. Nolinsk,	57 33	49 56
53. Slobodskoi,	58 44	50 12
54. Omoutninsky Zavod,	58 40	52 33
*55. Glasoff,	58 8	52 41
56. Debessy,	57 38	54 0
57. Ohansk,	57 43	55 23
58. Perm,	58 1	56 16
59. Koongoor,	57 26	56 58
*60. Choossowaia,	58 1	57 30
*61. Cooshwinsky Zavod,	58 1	59 12
*62. Verhne-Toorinsky Zavod,	58 30	59 30
*63. Nijne-Toorinsky Zavod,	58 40	59 45
64. Nijne-TagilskyZavod,	58 3	60 19
65. Verhotoorie,	58 51	60 48
66. Trbit,	57 30	63 0
67. Toorinsk,	58 3	63 40
*68. Tobolsk,	58 12	68 13
69. Tomsk,	56 30	84 56
70. Kolgonskaia,	56 25	86 10
71. Mariinsk,	56 18	87 44
*72. Atchinsk,	56 16	90 30
*73. Krasnoiarsk,	55 1	92 50
*74. Ooiarskaia.	54 50	94 20
75. Kansk,	56 12	95 39
76. Birusinskaia,	54 50	97 5
77. Nijne-sodinsk,	54 55	99 2
78. Tooloonowskoe,	54 40	99 52
79. Kimilteiskoe,	54 10	100 30
80. Cheremhowskoe,	53 10	102 15
81. Trkootsk,	52 16	104 16
82. Mansoorskaia,	53 45	106 0
83. Cabanskoe,	52 2	106 15
84. Verhneoodinsk,	51 50	107 35
85. Coolskaia,	52 12	109 47
86. Possiet,	42 55	120 40
87. Nowgorodskaia,	42 50	120 50

† 12 kilometers from Torjok is the private observatory of General Majeffsky.
‡ 2 kilometers from Kineshma is the private observatory of Professor Bredichin.

To this already very long and favorable list of places, we might add several stations in Japan, at which telegraphic connection might, by suitable prearrangement, be without doubt secured.

As Dr. Glasenapp remarks, the coming eclipse will afford a good occasion for astronomers to observe the phenomena in coöperation, and this coöperation may become very extended, if the telegraph is used in the manner proposed.

ART. XXVII.—*On two new Meteorites from Carroll County, Kentucky, and Catorze, Mexico;* by GEORGE F. KUNZ.

TWO meteorites have recently come to me for description, which are of more than ordinary interest, both on account of their peculiar composition and structure, and also because of their ethnological relations. The mass from Carroll County, Kentucky, is especially interesting because of its probable connection with the meteoric iron found in the Turner mounds.

1. *Carroll County, Kentucky, Meteorite.*—In the spring of 1883, Professor F. W. Putnam found on the altar of mound No. 3 of the Turner group of mounds in the Little Miami Valley, Ohio, several ear ornaments made (see fig. 1)* of iron and several others overlaid with iron. With these were also found a number of separate pieces that were thought to be of iron. They were covered with cinders, charcoal, pearls (two bushels were found in this group of mounds), and other material cemented by an oxide of iron, showing that the pieces had been subjected to a high temperature. On removing the scale Dr. Kennicutt found they were made of iron of meteoric origin.† One of the pieces weighed 28 and another 52 grams.

1.

Earring made of Meteoric Iron.

In the autumn of 1883, another mass was found on the altar of mound No. 4 of this same group, which weighed 767·5 grams (27¼ ozs.). Dr. Kennicutt suggests that these were all parts of some larger meteoric mass. The results of the inves-

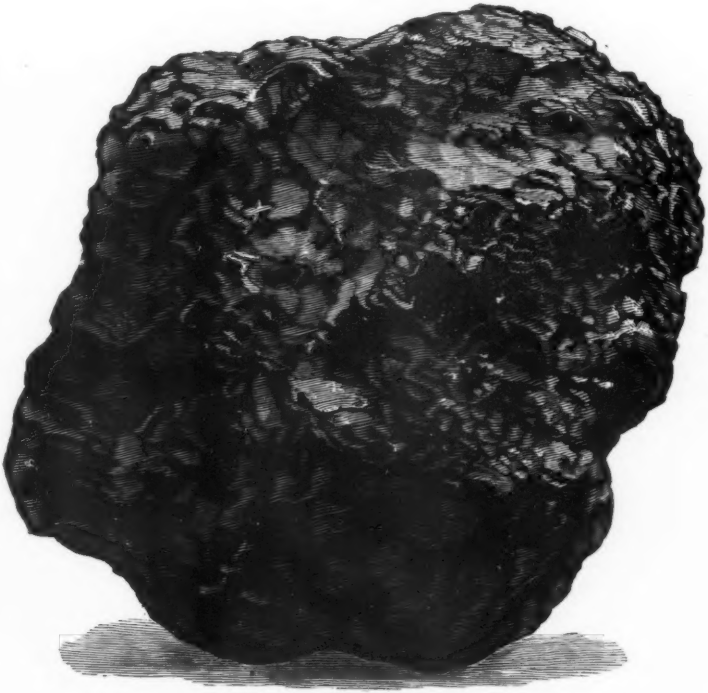
* I am indebted to Professor Putnam for the cuts from which figures 1 and 5 are printed, as also for the information he has kindly furnished me.

† 16–17 Report of Peabody Museum of Archæology, p. 382.

tigation were published in connection with the description of the Atacama meteorites, because in structure they approached more closely to the latter than to those of any other occurrence. In the Liberty group of mounds in the same valley, Professor Putnam found a celt five inches long, and in another of the Turner mounds, an ornament five inches long and three inches wide, made also of this same meteoric iron.

It was not until after the above masses had been found that the Carroll County meteorite was brought to my notice; after a careful comparison I have reached the conclusion that the irons from the Ohio mounds and the Carroll County meteorite

2.



Carroll County Meteorite, upper side, ½ natural size.

probably belong to one and the same meteoric fall. Either the former was broken from the main mass by the mound-builders or they were all fragments of the same fall scattered as were the Estherville meteorites, or as suggested by Dr. J. Lawrence Smith, those of Coahuila, and further, by Huntington,* the Sevier, Cocke County, and Jenny's Creek irons.

* This Journal, III, xxxiii, p. 115.

The Carroll County meteorite was found in 1880, about ¾ of a mile from Eagle Station, Carroll County, Kentucky, ten miles from the mouth of the Kentucky River and about seven miles in a direct line from both the Kentucky and the Ohio Rivers. The distance to the Turner mounds, where Professor Putnam found the meteoric iron and the ornaments made of it, is about 60 miles. The mass, which weighs about 80 lbs. or 36·5 kilos (figs. 2 and 3), is almost square, measuring 19^{cm} (7½

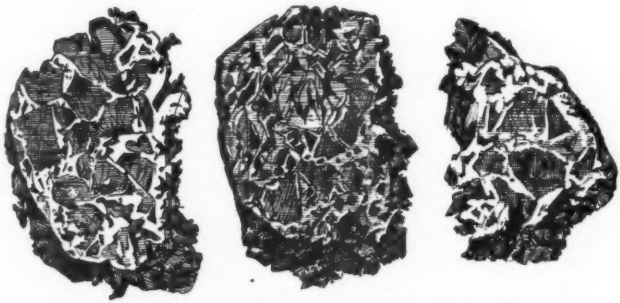
3.

Carroll County Meteorite, lower side, ⅓ natural size.

inches) in thickness, 22^{cm} (10 inches) in width and 29^{cm} (12 inches) by 29^{cm}, 12 inches in length. The surface is rusted in some places to a depth of 10 to 12^{mm}, and deep pits, some 2^{cm} across, are observed in spots where grains of olivine have probably dropped out. All of the original crust has disappeared. The mass is largely made up of fine yellow, transparent olivine, resembling closely that of the famous Pallas iron. This meteorite belongs to the siderolites or "syssidères" of Daubrée, and the Pallasite group.

Figure 4 shows three sections of the Carroll County mass, the

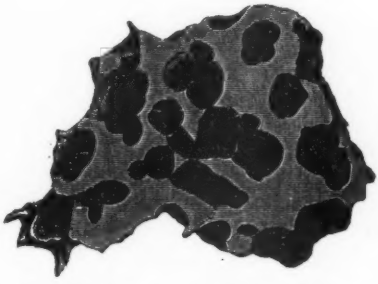
4.



Sections of the Carroll County Meteorite. Natural size.

light portions representing the iron and the dark portions the olivine. Figure 5 shows a similar section made by Dr. L. Kennicutt, of the Turner Mound mass. The specific gravities

5.



Section of the iron from the Turner Mounds.

of the three sections figured are given below, with those of the Atacama and Turner's Mound meteorites.

No.	Carroll County.		Turner's Mound.	Atacama.
1	4·21	mean	4·72	4·35
2	4·379	4·41		
3	4·66			

Taking the specific gravity of the iron at 7·6, and that of the olivine at 3·3, we find that all of these meteorites consist of about three parts of olivine to one part of iron. The iron in the Carroll County meteorite is scarcely more than sufficient to hold the mass together securely, as the olivine is in so much larger crystals than in the Atacama meteorite. On etching, small, fine Widmanstätten markings are produced. By re-

flected light minute crystals of bronzite can easily be recognized, and analysis showed the presence of chromite in fine grains and a very small quantity of schreibersite. The analyses of the olivine and iron were kindly furnished by Mr. James B. Mackintosh of Lehigh University. The sample of the iron taken was selected, as he states, as carefully as possible, to ensure purity, but it was found impossible to free it entirely from earthy matter. The sample of olivine was also somewhat contaminated with foreign matter.

	1.	1a.		2.		
Olivine,		G.=3·47.		Metallic Portion.		
SiO_2	37·90	39·36	Fe	73·44	or Fe	71·73
MgO	41·65	[41·83]*	Ni	14·27	Ni	14·27
FeO	19·66	18·81	Co	0·95	Co	0·95
MnO, CoO	0·42	----	P	0·05	P	0·05
	99·63	100·00	SiO_2	4·23	Olivine	11·12
			MgO	4·69	Chromite	0·90
			Chromite	0·90		99·02
				98·53		

* By difference.

The balance in the last analysis is oxygen in the form of iron oxide, and undetermined constituents. For the pure metallic portion we obtain then A below, or B on the assumption that the deficiency in the analysis is chiefly oxygen combined with iron as magnetic oxide.

	A.	B.
Fe	82·45	81·92
Ni	16·40	16·90
Co	1·09	1·12
P	0·05	0·06
	100·00	100·00

For comparison, analyses of the olivine and iron from the Turner mound and Atacama meteorites are added.

	Olivine.			Iron.	
	Turner Mound.* G.=3·336.	Atacama.† G.=3·33.		Turner Mound.*	Atacama.‡
SiO	40·02	----	36·92	Fe 89·00	88·01
FeO	14·06	Fe_2O_3	17·21	Ni 10·65	10·25
MnO	0·10	Mn_2O_3	1·89	Co 0·45	0·70
MgO	45·60	----	43·90	Cu tr.	----
				P ----	0·33
				Na ----	0·21
				K ----	0·15

* Kennicutt, loc. cit. † Schmid, Pogg. Ann., lxxxiv, 501.
‡ Buchner, Die Meteoriten, Giessen, p. 195, 1859.

2. *Catorze meteorite.*—The Catorze mass (fig. 6), weighing 92 lbs., was found by a miner near Catorze, San Luis Potosi,

6.

Catorze Meteorite; ¼ natural size.

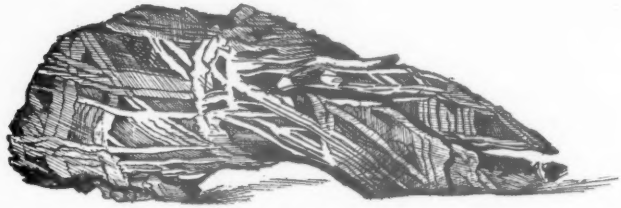
Mexico, in 1885. It is 31·5^{cm} (12½ inches) long, 34·5^{cm} (13½ inches) wide, and 20^{cm} (8 inches) thick. It shows beautiful raised octahedral markings. On one side an opening 9^{cm} (3½ inches) long has been made, and a piece of a chisel of native copper left wedged in it (fig. 7). This piece, which is partially covered with oxide of copper, is 22^{mm} (⅞ inch) long on one side, 33^{mm} (1¼ inch) on the other, and 14^{mm} wide.

7.

Catorze Meteorite, showing copper chisel (*c*); natural size.

This iron is one of the Caillite group of Stanilas Meunier and shows the Widmanstätten lines very finely (see fig. 8),

8.



Catorze Meteorite, Widmanstätten Figures; natural size.

It resembles the irons of Augusta County, Virginia, of Glorieta Mountain, and others of this group. No troilite was observed, the mass having been cut very little, and schreibersite is only sparingly present.

The specific gravity of the piece was found to be 7·509, the analysis by James B. Mackintosh, E.M., of Lehigh University, is given below. To this are added analyses of masses found nearest to Catorze, since G. V. Bogulawski suggests that perhaps the Charcas, Zacatecas and Durango irons were all parts of one fall.*

	Catorze. Mackintosh.		Toluca. Wöhler.[1]	Toluca. Wöhler.[1]	Charcas. Stan. Meunier.[2]
Fe	90·09		90·43	87·894	93·01
Ni, Co	9·07		7·62, 0·72	9·056, 1·070	4·32
P	0·24		0·15	0·620	----
Scale insoluble in HNO_3	0·60	Insoluble in HCl.	0·34	0·224	0·70
Schreibersite	----		0·56	0·344	----
S	----		0·03	----	----
CuSn	----		0·03	----	----
Mn	----		----	0·201	----
	100·00		99·88	99·409	98·03
Sp. gr.	7·509				

[1] Wöhler Sitzber. K. Akad. Wiss., xx, 217. [2] Meunier, Encycl. Chim., ii, 118.

Del Rio† mentions that two of his pupils found above the Aqua Blanca Estate, native iron in a conglomerate rock in a vein from one to two fingers in width. Burkart‡ says that he saw, in the possession of Señor Chialiva in Zacatecas, a mass of meteoric§ iron weighing between ten and twelve pounds that was said to have been found in the vicinity of Catorze—or rather Alamos de Catorze as it is known—which is in San Luis Potosi, about 200 miles southwest of Durango, 40 miles north of Charcas, and 340 miles north of Toluca. There is also in the Museo Nacionale of the City of Mexico a mass‖ weighing 576 kilos which was found at Descubridora in San Luis Potosi; it was described in 1873.

The well-known Charcas mass, weighing 780 kilos, was found in the corner of the church at Charcas, San Luis Potosi, Mexico, by some French soldiers and taken by them to Paris in 1866. This mass was first mentioned by Sonnenschmid,¶ and afterwards by Humboldt.** From all appearances, however, I am inclined to believe that the iron now under consideration is a new and distinct fall.

* Pogg. Ann., iv, 1, 1854. † Tablas Mineralogicas, vol. i, p. 57; ii, p. 40.

‡ Neues Jahrbuch für Mineralogie, 1856, p. 286.

§ Perhaps part of the iron here described, since it showed an old break on one side.

‖ A specimen of this iron in the Yale University Collection, received from Professor Barcena is accompanied by a copy of an analysis by P. Murphy, as follows: Fe 89·51, Ni 8·05, Co 1·94, S 0·43, Cr and P 0·95=100.—Eds.

¶ Berg. Rev., Mexico, p. 228, 1804.

** Essai Politique, Paris, 1811, vol. iv, p. 107.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the production of Fluorine by the electrolysis of Hydrogen Fluoride.*—In June last, Moissan communicated to the French Academy the results which he had obtained by submitting liquid hydrogen fluoride to electrolysis. The anhydrous liquid was contained in a V-tube of platinum cooled to −50°, and the current needed was supplied by 50 Bunsen cells. Hydrogen was evolved at the negative electrode, and there appeared at the positive electrode a gas having the following properties: In contact with mercury it was completely absorbed, forming yellow mercurous fluoride; with water, it formed ozone; phosphorus spontaneously inflamed in it, forming phosphorus fluorides; sulphur heated and melted; carbon had no action; fused potassium chloride was attacked in the cold, evolving chlorine; crystallized silicium, carefully purified, took fire in the gas, producing silicium fluoride. The positive electrode of platinum-iridium was corroded, while the negative electrode of platinum was not affected.

In a second paper, the author gives the details of subsequent experiments. The hydrogen fluoride was obtained pure and anhydrous by heating hydrogen-potassium fluoride in a platinum alembic, and collecting the product in a platinum receiver immersed in ice and salt. In this way a colorless liquid was obtained, boiling at 19·5°, very hygroscopic and fuming strongly in the air. The platinum V-tube used for the electrolysis carried a small evolution tube near the top of each limb. Its ends were closed by stoppers of fluorite, through which passed platinum rods to serve as electrodes; that on the positive side being alloyed with ten per cent of iridium. This V-tube was placed in a glass jar and surrounded with methyl chloride. The liquid hydrogen fluoride was then transferred to it, the methyl chloride boiling quietly at −23°, and the current of 20 Bunsen cells, having an ammeter in circuit, turned on. If a trace of water be present, ozone is at first evolved; and then as it disappears, the resistance of the liquid rises; so that the current ceases when it becomes anhydrous. A small quantity of hydrogen-potassium fluoride must therefore be added; and then the evolution of gas is continuous and regular. At the positive electrode this gas is colorless, and silicium takes fire and burns brilliantly in it, as does adamantine boron, arsenic, antimony, sulphur and iodine. The metals also burn in it but less actively. Organic matters are violently attacked by it. A fragment of cork, near the delivery tube, took fire, and alcohol, ether, benzine, turpentine and petroleum are at once inflamed on contact with it. The gas combines with hydrogen spontaneously in the cold and with detonation. Since direct experiment showed that neither ozone saturated with hydrogen fluoride, nor hydrogen fluoride itself, would produce

these results, and that chlorine was entirely absent, the conclusion is that this gas is either fluorine itself or is a higher fluoride of hydrogen.

In a third paper, Moissan describes the production of this gas by the electrolysis of carefully dried hydrogen-potassium fluoride kept in fusion at 110°. But the apparatus is rapidly attacked. In electrolyzing the liquid hydrogen fluoride, a yield at each electrode of from one and a half to two liters of gas per hour, is readily obtained. To test the question whether this gas contained hydrogen, it was passed over red-hot iron. The delivery tube was connected first with a platinum tube containing dry potassium fluoride, to absorb any hydrogen fluoride; and second, with a similar tube, also 20^{cm} long, containing a bundle of iron wires and previously tared. To the end of this tube is attached, by means of a rubber joint, first a test tube and then a flask both inverted and filled with pure carbon dioxide. The liquid hydrogen fluoride is cooled to −50° by passing a rapid current of air through the surrounding methyl chloride, and the current is turned on. Immediately the platinum tube containing the iron is raised to incandescence by the chemical action going on within it, the form of the brilliantly burning wires being visible through the walls. After ten minutes, the operation was closed and the tube weighed. The iron was found as white crystallized fluoride, and on examining the collected gas remaining after absorption of the CO_2 by potassium hydrate, it was found to be only the air which the platinum tubes had contained. On the negative side 78^{cc} of hydrogen was collected, weighing 0·006942 gram. Multiplying this by 19, to give the corresponding weight of the fluorine disengaged, gives 0·132 gram; the increase in the weight of the iron having been 0·130 gram. Hence the gas obtained must be fluorine.—*C. R.*, cii, 1543; ciii, 202, 256, July, 1886. G. F. B.

2. *On Methods of avoiding errors due to polarization, in the use of double image prisms.*—In order to measure the relative intensity of two images, a double image prism is often employed. Two images of A and B are thus brought near together and polarized at right angles. These images are observed with an analyzer, which is attached to a divided circle, and which allows the equalization of the images. When the original bundle of rays is polarized, the photometric measures are complicated, since the double image prism acts itself as an analyzer and alters unequally the intensity of the two sources of light. Thus it is necessary to make a preliminary determination of the amount of error thus introduced. M. Cornu believes that the cases in which the bundle of rays are partially polarized are more frequent than is generally supposed and gives several methods of avoiding this error. These methods are simple and are explained in detail in his article.—*Comptes Rendus*, Dec. 20, 1886, p. 1227. J. T.

3. *Electromotive force due to the Voltaic arc.*—Many efforts have been made to determine this contrary electromotive force; but the results obtained by different observers have not been concor-

dant. LEO ARONS has applied to this problem, with certain modifications, Cohn's method for the measurement of polarization in fluids (Wied. Ann., xiii, 665, 1881), which in general terms is as follows:—One branch of a Wheatstone's bridge contains the polarizing element and the liquid. In place of the latter a metallic resistance can be interposed. The bridge contains a galvanometer and one coil of a dynamometer, while the other with the secondary coil of an induction apparatus forms the second diagonal of the parallelogram. The resistance together with the interposed liquid are so arranged that the dynamometer gives no indication when the induction coil is excited. At the same time the deflection of the galvanometer is read. Then the liquid is replaced by a metallic resistance until the dynamometer again gives no indication, and the galvanometer is again read. These observations can be applied to a simple expression which gives the contrary electromotive force of the liquid. Instead of the liquid the voltaic arc can be substituted. In preliminary trials, Arons, obtains with a current strength of 3·4 amperes, a contrary electromotive force, in the electric lamp employed, of 40·6 volts, together with an arc resistance of 2·1 ohms. With 4·1 amperes; the contrary electromotive force was 39·6 volts, and resistance 1·6 ohms. Arons is apparently unacquainted with the investigations of Professor Cross of the Massachusetts Institute of Technology upon this subject.—*Ann. der Physik und Chemie*, No. 1, 1887, p. 95–99. J. T.

4. *Generalization of the Wheatstone Bridge.*—O. FRÖHLICH investigates the conditions of equilibrium when sources of electromotive forces are interposed in one of the branches of the bridge or in one of its diagonals, and shows that Mance's method is only a special case of a more general law; and that the statement in Maxwell's Electricity and Magnetism, vol. i, p. 411, that Mance's method is the only one in which the current of the cell remains unchanged, is not correct.—*Ann. der Physik und Chemie*, No. 1, 1887, pp. 156–161. J. T.

5. *On a nearly perfect simple pendulum.*—Mr. J. T. BOTTOMLEY, of the University of Glasgow, suspends a small shot of about $\frac{1}{16}$ of an inch in diameter, by a single silk fibre (half a cocoon fibre) two feet long, in a glass tube three quarters of an inch in internal diameter and exhausts the latter to about one tenth of a millionth of an atmosphere. Starting with a vibrational range of $\frac{1}{4}$ inch on each side of its middle portion, the vibrations can be easily counted after the lapse of 14 hours.—*Phil. Mag.*, *Jan.*, 1887, p. 72. J. T.

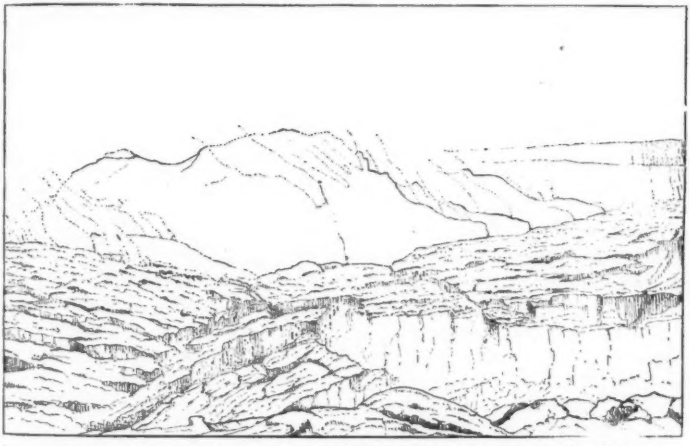
6. *Acoustical Investigations.*—F. MELDE continues his communications upon his acoustical experiments, with an account of the vibrations of bell-shaped vessels, together with the movements of fluids which they may contain. Ingenious methods of studying the movements of the fluids are given, together with the figures obtained. In certain cases a thin layer of petroleum covers the surface of the water, which fills the vessel; in other

cases light powder is sprinkled upon the water. The bell-shaped vessels are set with vibration in various ways.—*Ann. der Physik und Chemie*, No. 1, 1887, pp. 161–189. J. T.

II. Geology and Mineralogy.

1. *Kilauea.*—The map of Kilauea by Mr. F. S. Dodge making Plate II, in the last number of this Journal, is reduced to one-fourth from the manuscript map received from Mr. Alexander, Director of the survey of the Islands, and the words on it, "scale 1:6000" should be changed to 1:24,000. Plate I is reduced to two-thirds the original; the scale is 1:18,000.

The writer is indebted to Prof. W. D. Alexander for a photograph (an outline copy of which is here given) of the cone *within* Halema'uma'u described by Mr. Dodge (p. 99.) It was taken from a point on the northeast edge of the pit on the 14th of last October, a few days after he finished his survey. In the copy the cone is in mere outline because the photograph fails to give any surface details. The height of the cone, as the figures in the explanation of the map, page 99, indicate, is very nearly that of the surrounding floor of Kilauea; and the height in the figure shows



The cone in Halema'uma'u from a photograph taken October 14, 1886.

that the view is one looking down into the pit, with the broken pahoehoe floor of Halema'uma'u (between its walls and the cone) in the foreground. The dotted lines indicate the positions of vapor-streams and clouds issuing from apertures in the sides of and about the cone; above it only vapors are indicated, as if those of the inside crater. The lower wall on the right is the wall of the northwest side of Halema'uma'u.

Mr. Dodge, in a letter dated January 14th, states that the cone is made of broken rock, large and small fragments, derived from

the fallen walls of the pit and old cones within it, material older therefore than the lava that surrounds it. He states that according to observations of others in November and early January the cone had increased in height so as to be one hundred and perhaps two hundred feet above the sides of the pit, instead of *on a level* nearly, as in early October; moreover the activity in the southwest part had increased and portions of the southwest wall had fallen in. J. D. D.

2. *The Origin of Mountain Ranges considered experimentally, structurally, dynamically, and in relation to their Geological History*, by T. MELLARD READE, C.E., F.G.S., etc., 360 pp. 8vo, with numerous illustrations. London, 1886. (Taylor & Francis).—The chief fact on which Mr. Reade bases his theory of the origin of mountains is that of the expansion of rocks by increase of heat. From his own numerous trials he arrives at 1/190,192 as the mean coefficient of expansion for 1° F., which is equivalent to 2·77 feet per mile for every 100° F. (which he takes at 2·75 feet). The special mean result for various sandstones arrived at by the author was 1/178,825; for marbles, 1/184,797; for slates, 1/193,827; for granites, 1/203,322. Mr. Reade observes that as expansion downward and laterally cannot take place, the whole is upward; consequently the rise of surface would be $3 \times 2{\cdot}75 = 8{\cdot}25$ feet nearly. Hence a crust 20 meters thick heated 1000° F., which would expand in each direction 550 feet (made the amount of consequent elevation by Lyell), would rise 1650 feet; and if the total rise went to form a ridge having a base one-tenth of the total area heated, the whole height would be 16,500 feet. A rising of molten or half-molten rock below would follow the rise; and the tension above would cause great fractures and this would lead to great denudation.

Periods of increased heat have alternated with those of diminished heat, and thus may have come contractions as well as expansions, and so alternations in conditions and in catastrophes, in the same mountain region. The increase of heat is due to a great increase in the thickness of sediments over the region,—the preliminary stage in mountain making, as first suggested by James Hall. This cause produces a rise in isogeothermal lines from below; and through this accession of heat the lower beds become most expanded. Thence come uplifts, fractures, flexures, faults, volcanic outflows, and the mountain range. The greatest mountain elevations have taken place in recent times because the Tertiary and Cretaceous rocks added vastly to the thickness of accumulations over large areas of the earth's surface.

Mr. Reade in illustrating his views, and opposing others, appeals chiefly to North American rocks for his illustrations and dwells especially upon the Appalachians of eastern America, and the Great Basin system studied by Powell, Gilbert and others, of western, quoting largely from American reports on the subjects.

As regards the Appalachians the conditions were just what the theory requires, if a thickness of 30,000 feet of rock in a sink-

ing geosynclinal trough, with such additions as may be assumed for loss by degradation, is sufficient. The accumulation began in the Cambrian, and ended, according to the present state of facts, with the Permian, taking for its completion all of Paleozoic time. Supposing the thickness of the deposits made to have been 50,000 feet, and the time elapsed during the making 50,000,000 years, the mean rate of sinking was 1 foot in 1000 years. The isogeothermal plane consequently rose at the mean rate of 1 foot in 1000 years, and the expansion through the rise of temperature went forward correspondingly, so far as was possible. At this rate the heating and the expansion continued in progress during the 50,000,000 years; and still, through all that time, *sinking* continued as the mean result. Such a rate of rise in the isogeothermal plane is so extremely slow—a thousandth of a foot a year—that it is hardly probable that the expansion could have been resisted through the long era to appear catastrophically at the end of it; and unless so it would seem that something more than a rise in the isogeothermal plane was needed in order to make the deposits into a mountain range.

The theory of mountain-making brought forward by Mr. Reade does not explain the inequilateral feature of most mountains. Like most others that have been presented, it takes little note of the system of events in the progress of the globe and the system of structure in the results of that progress. American geological study has made out plainly that there was first, in the continent, Archæan ranges of elevations of one or more epochs; that on the eastern border there were three or four other periods in the course of geological time when other ranges of elevations were made, but all parallel in general and often in special trend, with the Archæan, although stretching on for a thousand miles or more. The facts are similar, so far as is understood, in Western America. Here is system, working from a beginning, under some continued method of progress, ending in making a continent of systematic features. Mr. Reade says that "Dana looks upon the development of continental land as analogous to animal growth." Nothing could be farther from the truth; for all that the comparison used by the writer meant was that there was systematic progress, in some way, as much so as in animal development. There is system also in the courses of the feature lines of the globe, which courses are as far removed as possible from meridional as required by some theories. The fact that the writer formerly made all these results to depend on contraction from cooling and the nature of the earth's crust, shows that the accordance with animal growth, was only accordance with the universal law of progress or development (Man. Geol., p. 830). What theory now to attribute the results to he does not know; but he believes that no theory of mountain-making will find general acceptance that does not take this system of progress, of structure, of topographical features into consideration. If the speculator thinks, like Mr. Reade, the linear arrangement of islands of little importance, let him consider,

instead, the great depressions of the ocean's bottom between the lines which teach the same great truths with regard to the earth's features.

Mr. Reade's work is a valuable contribution to the perplexing subject of mountain-making; for the principle to which he appeals has greater importance than has been supposed. But something more appears to be needed to give the theory full sufficiency.

3. *Skeleton of a Whale found over* 130 *years since in the St. Lawrence River Valley, near Quebec.*—A letter to the editors from Professor O. P. Hubbard states that in Kalm's Travels in North America and Canada, on page 15 of the third volume, mention is made of the finding of the skeleton of a whale some French miles from Quebec and one French mile from the River St. Lawrence, "in a place where no flowing water occurs at present." The skeleton was of considerable size, and the Governor of Fort Frederick said he spoke with several persons who had seen it. Kalm, the Swedish botanist, was in America during the years 1748 to 1751, and he learned the fact in 1750.

4. *Geological History of Lake Lahontan, a Quaternary Lake of Northern Nevada;* by ISRAEL COOK RUSSELL. Volume xi of the Monographs of the U. S. Geological Survey, 288 pp. 4to, with 4 plates, the last a folded map, 1885.—An abstract of Mr. Russell's results after his first season's work, published in the third Annual Report of the Director of the U. S. Geological Survey, has been briefly mentioned in a former volume of this Journal. The final Report, recently issued makes a volume of great general interest and scientific importance. The facts relating to the Lahontan Lake basin of the past and present, its terraces, the chemistry of its waters, the remarkable tufa deposits of the terraces, the lake and shore-made beds of sand, gravel and clays (the last largely pumiceous), the life of the varying waters, the drying up of the lake with the climatic changes, and the later Quaternary orographic movements, have all been carefully studied and a large amount of instruction drawn from them for physical geography, geology and economical science. The many maps and plates, illustrating the volumes are excellent. The descriptions of the thinolite tufa deposits and of the conditions of their origin are illustrated by several fine plates, and supplemented by extracts from a crystallographic study by E. S. Dana.

5. *The Geographical and Geological Distribution of Animals;* by ANGELO HEILPRIN, Prof. Invert. Paleontology, etc., 436 pp. 12mo. New York, 1887 (D. Appleton & Co.).—Professor Heilprin has endeavored to combine in this work a consideration of the geographical distribution of existing faunas with that of the ancient, and so present a general review of the historical as well as actual associations of species. The subject is a very broad one for the space allotted to it; but it has been so handled as to make a valuable and readable work for students in both geology and biology.

6. *Manual of Mineralogy and Lithology*, containing the elements of the science of Minerals and Rocks for the use of the practical Mineralogist and Geologist and for instruction in Schools and Colleges; by JAMES D. DANA, 4th edition, 518 pp. 8vo, New York, 1887 (John Wiley and Sons).—This new edition of the author's "small" mineralogy, like the preceding, places together, all the ores of the same metal, and in this and other ways the Manual is adapted to the needs of the mining and practical mineralogist. As the preface states, the work has been revised throughout, and brought down to the year 1886 in its descriptions and in the introduction of new species; and the chapter on Rocks has been revised, rearranged, much enlarged, and supplied with additional illustrations.

7. *On the chemical composition of the orthoclase in the Cortlandt Norite.* (Communicated.)—Since the publication of the writer's description of this interesting mineral in the February number of this Journal (p. 139), a complete analysis of it has been made by Mr. Wm. M. Burton of the Chemical Laboratory of the Johns Hopkins University. The results are worthy of publication as placing beyond all doubt the nature of the mineral in spite of its very unusual association.

The material for analysis was separated by the Thoulet solution, all that portion of the rock being used which possessed a specific gravity of 2·62 or less. The results of two complete analyses of lead fusion (I–II) and one partial analysis of fusion with potassium and sodium carbonate (III) are as follows:

	(I.)	(II.)	(III.)	(Mean.)
SiO_2	61·71	61·76	61·65	61·71
Al_2O_3	21·50	21·36	21·55	21·47
CaO	2·82	2·70	----	2·76
K_2O	12·74	12·88	----	12·81
Na_2O	·88	1·04	----	·96
Total	99·65	99·74	---	99·71

Now on account of the very intimate admixture of the orthoclase with the accompanying and included andesine, it was doubtless impossible to perfectly separate the two minerals, as is made more probable by the specific gravity which is somewhat high for orthoclase. If, therefore, we deduct from the above mean analysis the amounts of SiO_2 and Al_2O_3 necessary to satisfy the 2·76 per cent of CaO and 0·96 per cent of Na_2O in the anorthite and albite molecules respectively, we obtain: 50·23 per cent SiO_2, 14·75 per cent Al_2O_3 and 12·81 per cent K_2O; and these proportions, calculated as percentages, give: SiO_2 64·57, Al_2O_3 18·96, K_2O 16·47, while the proportions calculated from the formula $K_2Al_2Si_6O_{16}$ are: SiO_2 64·68, Al_2O_3 18·43, K_2O 16·89.

GEORGE H. WILLIAMS.

Baltimore, Feb. 18th, 1887.

8. *Nickeliferous metallic Iron from New Zealand* (from a letter to the Editors dated Dunedin, October 14, 1886).—In the drift of the Gorge River (which empties into Awarua or Big Bay, on the west coast of the middle island of New Zealand), derived in part from the so-called "Red Hill"—a high mountain mass consisting of older peridotite, more or less converted into serpentine—there occurs, associated with gold, platinum, cassiterite, chromite, magnetite, a nickel-iron alloy. According to an analysis by Mr. W. Skey, our government analyst, it is composed of Ni 67·63, Fe 31·02, Co 0·70, S 0·22, SiO_2 0·43, and has the formula Ni_2Fe. Specific gravity 8·1 and hardness about 5. This as a new mineral he has named *Awaruite*. Mr. Skey also discovered the curious fact of this alloy not being able to reduce copper from its acid solution of cupric sulphate and argues from this the unreliability of the copper test for demonstrating the absence of iron alloys from rock masses. That the new alloy has been derived from the peridotite (olivine-enstatite rock, as far as I have found) of the Red Hill there can hardly be a doubt, as specimens of serpentine—partly resembling the antigorite, partly picrolite—have been found on the mountain, containing specks of it abundantly impregnated. It is certainly a very close terrestrial relative of the iron meteorite, octibbehite (FeNi), mentioned in Dana's System of Mineralogy and in Wadsworth's comprehensive table of analyses, given in "Lithological Studies," as found in Octibbeha Co., Mississippi. GEORGE H. F. ULRICH.

III. Botany and Zoology.

1. Minor Botanical Notes.—That immense repertorium of botany, Baillon's *Dictionaire de Botanique*, makes steady progress. Fascicle 21, which is the first of vol. ii (pp. 104), carries the letter H down to the article *Hypericum*.

Of *Hooker's Icones Plantarum*, the third and concluding part of vol. xvii—a Fern volume—was issued in January. The North American and Northern Mexican species figured are *Nothochlæna Palmeri*, Baker, and *N. Hookeri*, Eaton.

H. N. Patterson, of Oquawka, Illinois, has brought out a new and attractive *Check-List of North American Plants, including Mexican Species which approach the U. S. Boundary*. It fills 150 large 8vo pages in double columns, of rather large and very clear type, printed upon one side only of the paper, and sufficiently spaced for cutting up into labels, when that is desired, or for intercalation of new names.

Dr. W. F. Tolmie, who died at Victoria, British Columbia, toward the close of last year, was one of the last survivors of those men of the Hudson Bay Company's service in its palmiest days who helped to develop the botany of our northwest coast. He was, we believe, one of Sir William Hooker's pupils at Glasgow, and, going out to Fort Vancouver as medical officer in 1832, he became one of the principal contributors of materials from that

district for his Flora Boreali-Americana. In that work he is commemorated by a peculiar genus of *Ericaceæ*, which, however, had been previously named by Bongard upon specimens from Alaska. Consequently the name of *Tolmiea* was applied in Torrey and Gray's Flora to a peculiar saxifragaceous plant of that coast. In his later years Dr. Tolmie devoted himself very much to the ethnology and linguistics of the Indian tribes with which he had so long been intimate. His name should have appeared in the botanical necrology of the year 1886. A. G.

Professor Delpino, who as early as in the year 1873 announced the idea that most extra-floral nectar-glands in plants are useful to the plants that bear them, by attracting a body-guard of ants, has now published the first part of an elaborate memoir on the topic. His *Prodromo d'una Monografia delle Piante Formicarie*, taking up the orders *seriatim*, although in this first part it includes only the Polypetalous and a few of the earlier Gamopetalous orders, fills 111 pages, 4to, in the Memoirs of the Royal Academy of Sciences of Bologna, ser. 4, tome vii, 1886. The number of species recorded as having *extra-nuptial* glands is much larger than would have been expected. This term 'extra-nuptial' is coined to distinguish the glands under consideration from certain extra-floral glands which, no less than those in the flower, are subservient to pollination. The *funzione myrmecofila* performed by the ants so attracted and fed is the keeping off of caterpillars and other insects which prey upon the foliage, young fruits, etc. Fruit-growers and tree-planters, thankful though they be for these small favors, must wish that this *function* were still more extensive and effectual. A. G.

The February number of the Botanical Magazine gives a figure of the new Compass Plant, *Silphium albiflorum*, Gray, a very recently published species, from Texas, raised in England from seed sent by one of its discoverers, Mr. Reverchon, whose name in the Botanical Magazine unfortunately appears as a place instead of a person.

Alphonse de Candolle has a short article in the Archives des Sciences of January 15, on the botanical origin of some cultivated plants. It treats mainly of *Vicia Narbonnensis* and *Vicia Faba*, and goes against the idea of Bentham that the latter (the proper bean of Europe) is a cultivated derivative of the former. It is also maintained that wheat should be regarded as a species distinct from *Triticum Spelta* and *T. monoccoccum*, notwithstanding that some recent experiments have been successful in intercrossing them. Horse Bean (*Vicia Faba*), Chick-pea, Lentils, Wheat, and Maize,—species of which the botanical originals appear to be extinct,—all agree in having large farinaceous seeds, therefore peculiarly subject to be eaten up by animals, such as mice, etc. To such depredations, M. de Candolle suspects that the unguarded native types of those species may have succumbed.

2. *Bibliotheca Zoologica II.* Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom

Jahre 1861–1880 selbstständig erschienen sind etc., von Dr. O. TASCHENBERG. Lief 1, pp. 1–320; 2, pp. 321–640. 8vo, Leipzig, 1886 (Wilhelm Engelmann).—The former issue of the Bibliotheca Zoologica in 1861 under the editorship of Professor V. Carus contained a catalogue of zoological papers published during the years 1846 to 1860. The present work, of which two parts are now completed, with Dr. O. Taschenberg as editor, is to continue and complete this great undertaking for the period from 1861 to 1880. In style and method the present volume corresponds to those issued twenty-five years ago. The first part opens with the literature, a list of catalogues of books, and then a very minute and exhaustive enumeration of periodical publications of all kinds, with the number of pages, plates, etc., of each volume—this portion of the work covers nearly 200 pages. Then follow the lists of zoological memoirs and articles arranged by the author's name under a number of general heads, as: acclimatization, aquaria, museums, public and private collections, zoological gardens, laboratories and stations; the collection and preservation of objects of natural history and comparative anatomy; the microscope, and so on. This statement of the contents of Part I will give some idea of the nature and scope of the work. Evidences of the tireless industry of the editor and his never relaxing effort to ensure accuracy and completeness are apparent on every page. The value of such a work can hardly be overestimated at this time when the literature of the science is increasing so rapidly and the memoirs on the various topics are scattered through so wide a range of publications. It is difficult to see how any worker in the science can get along without it. The work when finished will fill twelve parts of about 320 pages each, forming four large volumes; the year 1888 is set as the time for its completion.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The American Naturalist.*—Professor A. S. Packard, for twenty years one of the editors of the Naturalist, and a large contributor to its pages, has withdrawn from it, and hereafter it will be in charge of Professor E. D. Cope.

2. *The Swiss Cross, A Monthly Magazine of the Agassiz Associations:* N. D. C. Hodges editor.—With January, the first number of this new Journal of Popular Science appeared, in a broad octavo form of forty pages. It promises to be a valuable journal for the distribution of scientific knowledge, right opinions, and news, and to be adapted not only for the young readers of the Agassiz Associations but for all who are interested in having science in a popular form. The Journal is published in New York at 47 Lafayette Place, at $1.50 a year or 15 cents a number.

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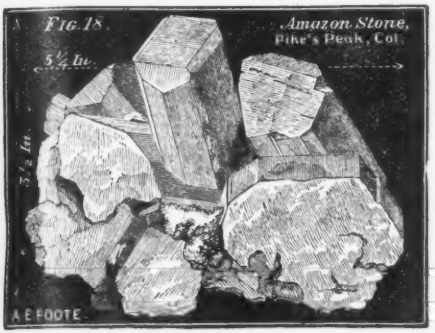

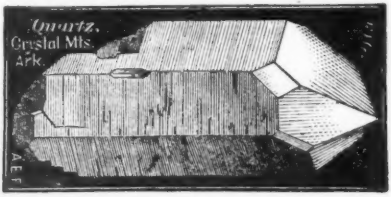

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